NASA-CR-193176

UPPER ATMOSPHERE RESEARCH SATELLITE

UARS

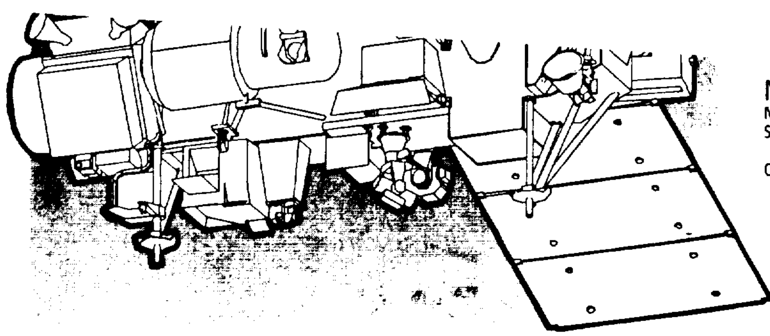
PROJECT DATA BOOK

(NASA-CR-193176) UPPER ATMOSPHERE RESEARCH SATELLITE (UARS) PROJECT DATA BOOK (GE) 265 p

N93-72798

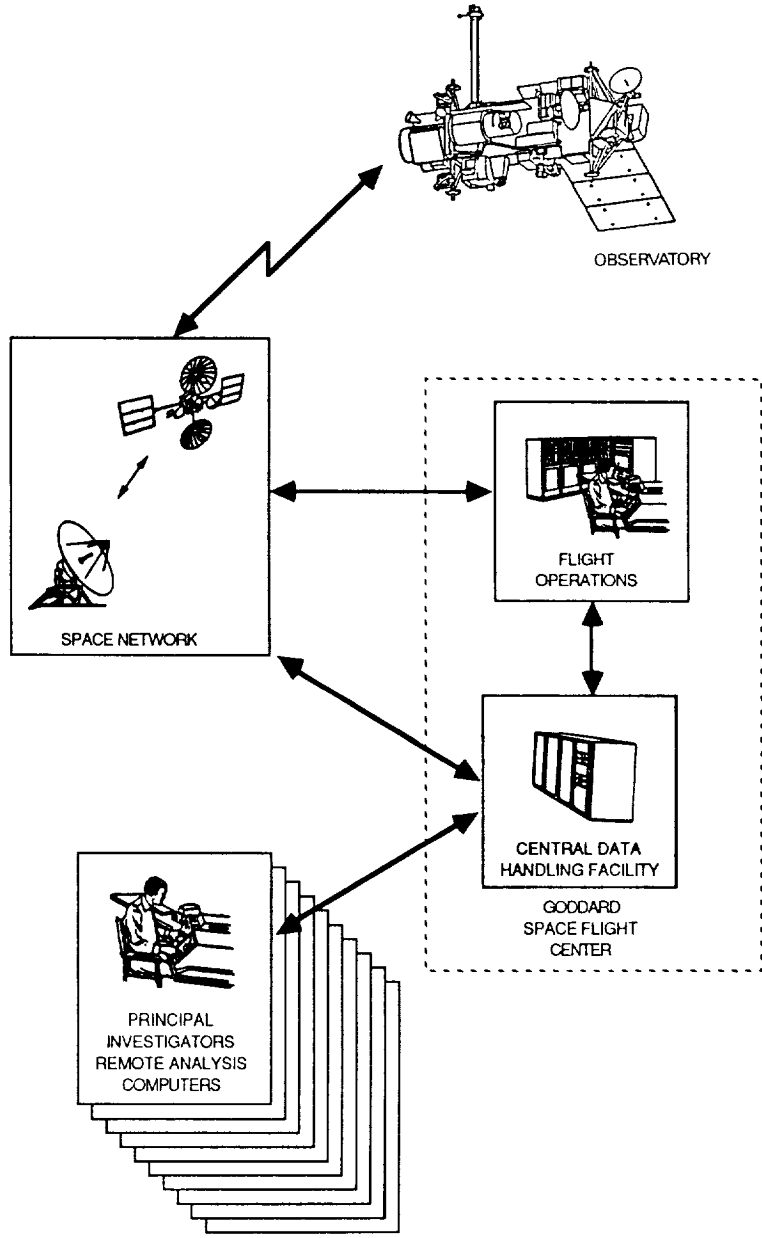
Unclas

Z9/ 0170667



NASA
National Aeronautics and Space Administration

Goddard Space Flight Center


OBSERVATORY
SPACE NETWORK
FLIGHT OPERATIONS
CENTRAL DATA HANDLING FACILITY
GODDARD SPACE FLIGHT CENTER
PRINCIPAL INVESTIGATORS REMOTE ANALYSIS COMPUTERS

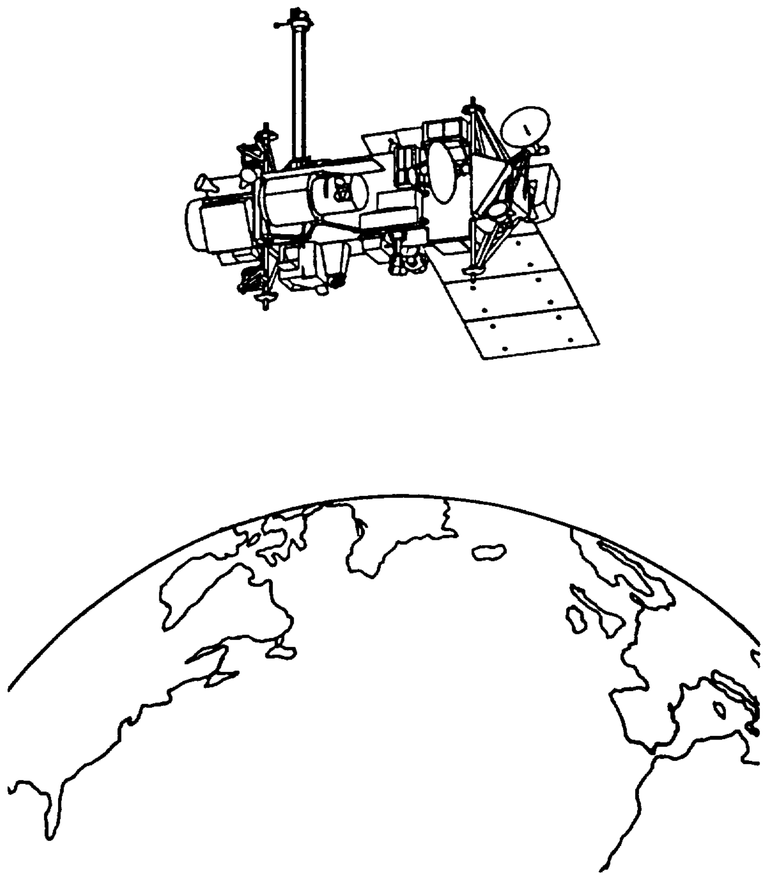
UARS SYSTEM

UPPER
ATMOSPHERE
RESEARCH
SATELLITE

PROJECT DATA BOOK

April 1987

GENERAL ELECTRIC
ASTRO-SPACE DIVISION



Preface: The UARS Project Data Book

In 1976, Congress amended the Space Act, directing NASA to undertake a comprehensive program of research into the upper atmosphere. The Upper Atmosphere Research Program was designed in response to that directive. The Upper Atmosphere Research Satellite (UARS), a shuttle-launched, Earth-orbiting observatory, is the center piece of that program.

Scientific studies have shown that natural events and human-related activities cause changes in the chemistry and physics of the upper atmosphere. These studies have led to concern that mankind's activities may be altering weather, climate, and the shield of ozone that is important to the protection of life on Earth.

Although studies to date have let researchers describe these changes in a general way, we lack the deep understanding that would permit accurate predictions and could be used as a basis for policy decisions.

The purpose of UARS is to provide data that will yield a better understanding of the upper atmosphere, and with it, a better understanding of the effects of natural events and human activity on that region.

This data book provides an introduction to the UARS mission and a comprehensive overview of the UARS system. The information in this data book was gathered primarily from technical memos, design review data packages, published reports, and handbooks.

Section 1 provides background and perspective. It gives an overview of upper atmosphere research to date, and it shows the role of the UARS mission in relation to other research.

Section 2 gives an overview of the UARS system, including the ground based portions of the system.

Sections 3 through 6 take a more detailed look at specific aspects of UARS.

The Appendices provide a list of UARS participants and contractors and a list of abbreviations and acronyms.

This data book was prepared by the Astro-Space Division of the General Electric Company, Valley Forge Spacecraft Operations, under contract with the NASA Goddard Space Flight Center, Greenbelt, Maryland.

CONTENTS

CONTENTS (Cont.)

CONTENTS (Cont.)

List of Figures

List of Tables

SECTION 1
THE UARS MISSION
(Background and Objectives)

Section **Page**

1. The UARS Mission (Background and Objectives)

1.1 Upper Atmosphere Research

1.1.1 The Problem: Changes in the Upper Atmosphere

For several decades scientists have sought to understand the complex interplay between chemistry, physical dynamics, and radiative processes that govern the structure of Earth's atmosphere. Much attention has now focused on the upper atmosphere, with particular concern about two areas: the possible effects of natural and man-made influences and the potential effects of changes in the upper atmosphere on such areas as climate, weather, and protection provided by the ozone layer.

Starting in the 1930s, balloons, rockets, and, most recently, satellites such as the Nimbus and the Explorer series have made measurements of several important features of the upper atmosphere. These have provided useful data on temperature, pressure, wind, and chemical composition.

These measurements have yielded important clues to the chemical nature and physical dynamics of the upper atmosphere. They have led to significant findings in areas ranging from the realization that the ozone layer is controlled by trace amounts of other substances, to an awareness of the significant role that winds play in energy transfer and trace gases in the upper atmosphere.

Until now, however, understanding has been limited by the lack of a comprehensive and fully integrated look at this region. Most measurements have been localized in space, limited in time, or both. The results have barely opened the door to our understanding. It's fair to say that studies to date have raised many more questions than they have answered.

For example, scientists have known for some time that life on the Earth's surface is dependent on the very small amount of ozone in the stratosphere. Only recently, however, have researchers realized that the quantity of stratospheric ozone is controlled by trace amounts of other substances.

The sources of these trace gases include certain man-made chemicals, as well as gases from naturally occurring biological processes. These gases are released globally and rise slowly into the upper atmosphere where they are broken apart by sunlight. Some of the resulting chemical fragments react with and destroy ozone.

What's more, these trace species are not themselves destroyed in the process. They remain in the atmosphere, where they continue to eat away at the atmospheric ozone.

These trace substances are typically present in concentrations that are thousands of times smaller than the concentration of ozone, so that even a small change in the absolute concentration of these substances can make a significant difference in the concentration of ozone.

Changes in the total amount of atmospheric ozone would affect the amount of biologically harmful ultraviolet radiation reaching the Earth's surface. This would have adverse effects on human health (skin cancer) and on the aquatic and terrestrial ecosystems — including still unassessed damage to food crops.

Equally important, changes in the vertical distribution of atmospheric ozone, along with changes in the concentrations of other gases active in the infrared, could modify the atmospheric temperature structure, and contribute to a change in climate on a regional and global scale (Figure 1-1).

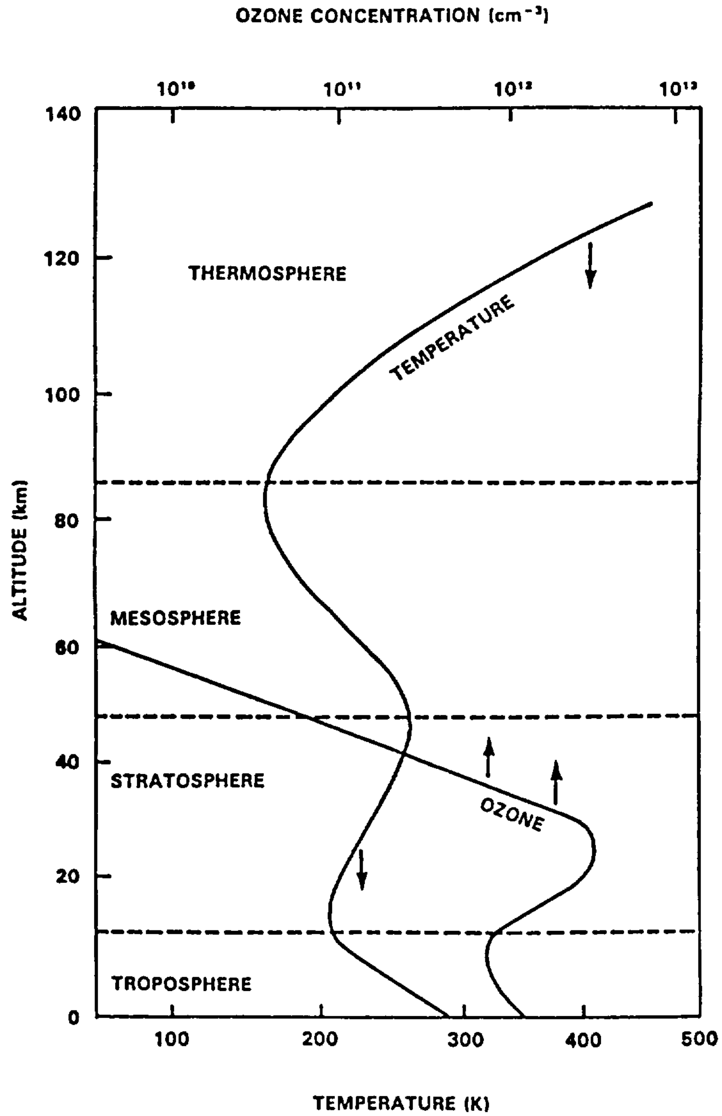


Figure 1-1. Changes in the vertical distribution of atmospheric ozone could modify the atmospheric temperature structure and contribute to a change in climate.

During the past decade, several technologies have been identified as contributors to the trace gases that relate to ozone depletion. These technologies include subsonic and supersonic aircraft that release nitrogen oxides, fertilizers that release nitrogen oxides, and various devices that release fluorocarbons, including spray cans, refrigerators, and air conditioners. Recently it has also become clear that these same technologies and gases are important in the climate issue.

Significant natural sources of trace species include outgassing from the Earth's interior, interchange of gases between ocean and atmosphere, interchange of gases between living organisms and the atmosphere, and interactions of atmospheric gases with energy from the sun.

There is already compelling evidence that the composition of the atmosphere is changing on a global scale. In recent years, measurements taken from balloons, sounding rockets, and satellites have detected increasing levels of ozone-destroying chemicals in the upper atmosphere, while data from the Nimbus-7 satellite have revealed a marked trend of ozone depletion in the atmosphere over Antarctica during the Southern Hemisphere spring (Figures 1-2 and 1-3). The amount of this decrease has grown steadily higher, recently reaching more than 40 percent.

1.1.2 The Goal: Understanding the Changes

The underlying goal of upper atmosphere research is to understand the chemistry, dynamics, and energy balance above the troposphere as well as the coupling between these processes and between atmosphere regions. This implies an understanding of the mechanisms that control upper atmosphere structure and variability, as well as an understanding of how the upper atmosphere responds to natural and man-made causes. Of particular concern is the effect of mankind's activities on the chemistry of the upper atmosphere.

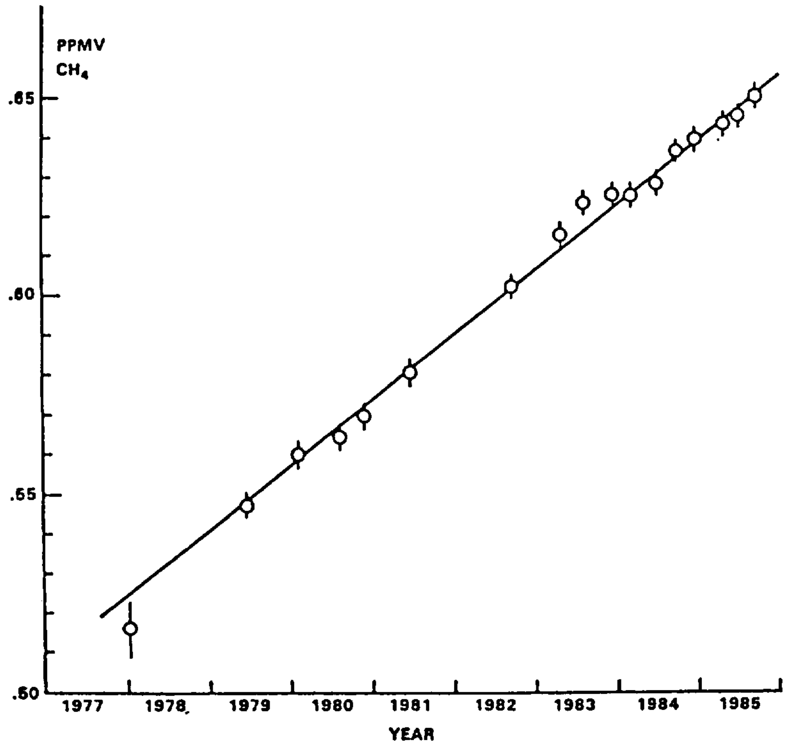


Figure 1-2. Globally averaged concentrations of trace gases such as methane (CH_4) have been steadily increasing. These gases may contribute to the depletion of ozone in the atmosphere.

(Ref: Present State of Knowledge of the Upper Atmosphere: An Assessment Report, NASA, January 1986.)

Because even minor changes in climate can have a major effect on such basic activities as food production, and because changes in the atmospheric ozone would have an important effect on the amount of biologically harmful ultraviolet radiation reaching the Earth's surface, this last area of study — the effect of human activity on the upper atmosphere — has important practical consequences for policies that could affect such activity.

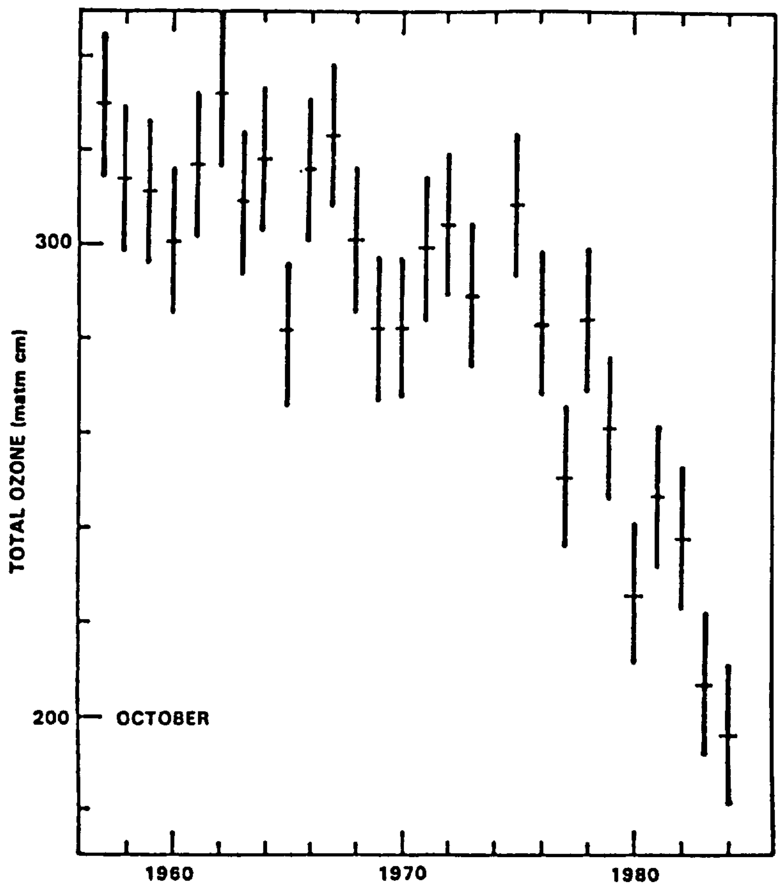


Figure 1-3. Ground based measurements in the Antarctic have shown a localized decrease in the amount of total column ozone since 1960. This decrease is seasonal showing up only in the Southern Hemisphere spring months of September and October.

(Ref: Present State of Knowledge of the Upper Atmosphere: An Assessment Report, NASA, January 1986.)

Recent advances in remote sensing technology and data processing technology now make it possible to investigate the changes in the Earth's atmosphere. Of particular note are advances in limb viewing techniques where measurements are made by viewing towards the horizon. These techniques were explored in satelites such as the Nimbus and Explorer series and have since been improved. (A pictorial representation of limb viewing is shown in Figure 1-4). Of equal importance are advances in computer technology that make it possible to deal with vast amounts of information.

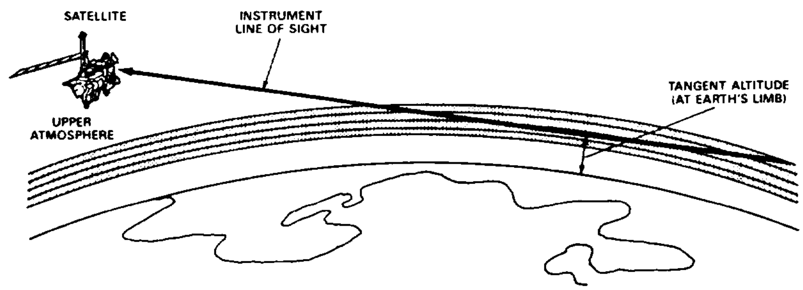


Figure 1-4. A pictorial representation of limb viewing.

NASA's research on the upper atmosphere takes advantage of these advances with the goal of answering some of the important questions about this region of the Earth's environment.

1.2 UARS Mission Objectives

1.2.1 A Global and Comprehensive Look

In 1976, Congress amended the National Aeronautics and Space Act, directing NASA to undertake research to understand the upper atmosphere and its susceptibility to change. The Upper Atmosphere Research Satellite (UARS) is a critical element in meeting that directive. It is part of a balanced effort aimed at gathering, processing, and interpreting the data that will help supply answers to questions about the Earth's upper atmosphere.

To fulfill the Congressional directive requires a continuous, global, and comprehensive look at the upper atmosphere over an extended period of time — with comprehensive defined to mean a coordinated and simultaneous set of measurements covering all important variables. This is best accomplished with all instruments carried on a single spacecraft, so that the measurements are easily correlated in time and space.

The UARS meets these needs. It takes advantage of both the recent advances in remote sensing technology and today's ability to put larger payloads into orbit — an ability that makes it possible to design larger, more sensitive satellite-borne instruments, all of which can be carried on a single spacecraft (see Figure 1-5).

The UARS observatory will provide simultaneous, coordinated measurements of atmospheric internal structure (trace constituents, physical dynamics, radiative emission, thermal structure, density) and measurements of the external influences acting upon the upper atmosphere (solar radiation, tropospheric conditions, magnetospheric particles, electric fields). In addition, the combination of orbit and instrument design will provide nearly global coverage.

The mission lifetime will span two Northern Hemisphere winters. (This is the season and area of the largest natural variations in the atmosphere.) The orbit was chosen to permit the distinction between daily and seasonal effects as well as providing nearly full global coverage.

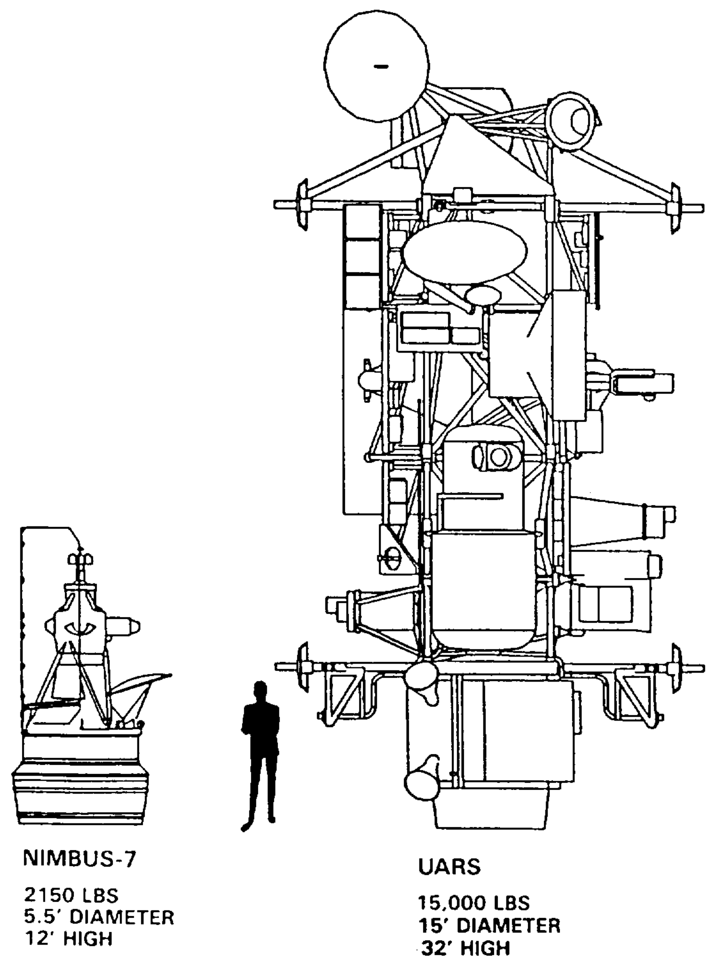


Figure 1-5. UARS carries more sensitive instrumentation than previous generations of spacecraft.

Data from the UARS satellite will be supplemented with information gathered from ground instruments, balloons, airplanes, sounding rockets, and other satellites. Taken together with laboratory studies and theoretical analyses, the data should yield the information researchers need to build accurate mathematical models of the Earth's atmosphere. The models, in turn, will let us understand and predict the reaction of the upper atmosphere to natural events and human activities. And given the ability to understand and predict these effects, we will also gain an understanding of how to protect this region of the Earth's environment.

1.2.2 UARS Objectives and Measurements

Program Objectives

The three major objectives of the UARS Program are essentially the same as the underlying objectives for upper atmosphere research in general. They are:

1. to understand the coupled energy input, chemistry, and dynamics as well as the coupling among these processes, all of which control upper atmosphere structure and variability.

2. to understand the response of the upper atmosphere to natural and human-caused changes.

3. to define the role of the upper atmosphere in climate and climate variability.

In addition to being directly responsive to NASA's congressional directive, these overall objectives and the method of implementation are consistent with recommendations made in the National Academy of Sciences report "Solar-System Space Physics in the 1980's: A Research Strategy."

Mission Objectives

The specific UARS mission objectives are to study:

1. energy input and loss in the upper atmosphere,
2. global photochemistry of the upper atmosphere,
3. dynamics of the upper atmosphere,
4. the coupling among these processes, and
5. the coupling between the upper and lower atmosphere.

These specific objectives are briefly explained in the following paragraphs.

Energy Input and Loss

Solar heating, combined with cooling by emission in the thermal infrared, produces most of the seasonal, latitudinal, and vertical variability of the thermal structure. This in turn controls most of the dynamics of this region. Therefore, a quantitative understanding of the atmospheric radiative processes is essential to investigations of the dynamics and chemistry of the upper atmosphere. UARS will measure solar ultraviolet radiation (input), particle sources (input), and radiative emission of constituents (loss).

Photochemistry

A qualitative understanding now exists of the sources, sinks, and budgets of most of the known upper atmosphere constituents. A quantitative understanding of atmospheric photochemistry is essential both to predict reliably the effect of perturbations (e.g., due to halocarbons and fertilizers) on the upper atmosphere and to assess the reliability of these predictions. UARS will make measurements of source and sink molecules of the nitrogen, hydrogen, and chlorine families and will make observations of short-lived derivatives (e.g., participants in chemical reactions such as ozone destruction). It will also make measurements of diurnal variations in atmospheric constituents.

Dynamics

Many constituents in the upper atmosphere have chemical lifetimes comparable to or longer than the time scales associated with transport phenomena. For these species, consideration of dynamics must accompany photochemical calculations to correctly explain observed constituent concentrations. UARS will measure motions on a global scale and will measure seasonal variations, with emphasis on Northern Hemisphere winters.

Coupling Among the Various Processes

The energetics, chemistry, and dynamics of the upper atmosphere cannot be treated in isolation from each other. They are highly coupled processes with both positive and negative feedbacks among them. The net effect of these couplings may be either to enhance or decrease the original ozone change. A full understanding of possible human-related perturbations to the ozone layer requires that the energy sources and sinks, photochemical processes, and dynamic processes be treated as a coupled system for the global upper atmosphere.

Coupling Between the Upper and Lower Atmosphere

In addition to the coupling processes already mentioned, it is essential to consider radiative, dynamic, and chemical coupling between the upper and the lower atmosphere. To establish definitively the role of the upper atmosphere in weather and climate, reseachers require global observations of the upper atmosphere and its dynamic links to the troposphere as well as extensive theoretical work. However, current forecast models of the lower atmosphere provide at least one indication that significant links exist: those models that include the stratosphere consistently give better forecasts than those that do not.

1.3 Mission Characteristics: Orbit, Coverage, and Resolution

The orbit altitude and inclination for the UARS mission are significant because the relationship of the satellite to both Earth and sun is important. That relationship is dictated by the requirements for the measurements to be made: temperature, pressure, chemical composition, particle environment, solar flux, magnetic field, and wind as a function of altitude, latitude, longitude, and time. These requirements, and the scientific justification for them, were first delineated by the UARS Science Working Group (SWG) and published in their final report in 1978.

Briefly, one set of requirements is that measurements should be global in nature and essentially continuous in time. The data should also allow researchers to distinguish between short-term local (solar) time effects and long-term latitudinal and seasonal effects, since each of these must be understood separately to build accurate models.

The spatial resolution requirements are half a scale height in the vertical (2.5 to 3 km) and 500 km in latitude (Figure 1-6). Longitude resolution requirements range from 1000 km to zonal means (i.e., the mean measurement for a band of atmosphere extending around the Earth parallel to the equator). This will depend on the specific study and the time scale of the measurement. The 500 km latitude resolution translates into about 1-minute time resolution along the satellite track. This defines a basic requirement for the atmospheric sensors to be capable of making vertical profile measurements in 1 minute or less (see Tables 1-1 and 1-2).

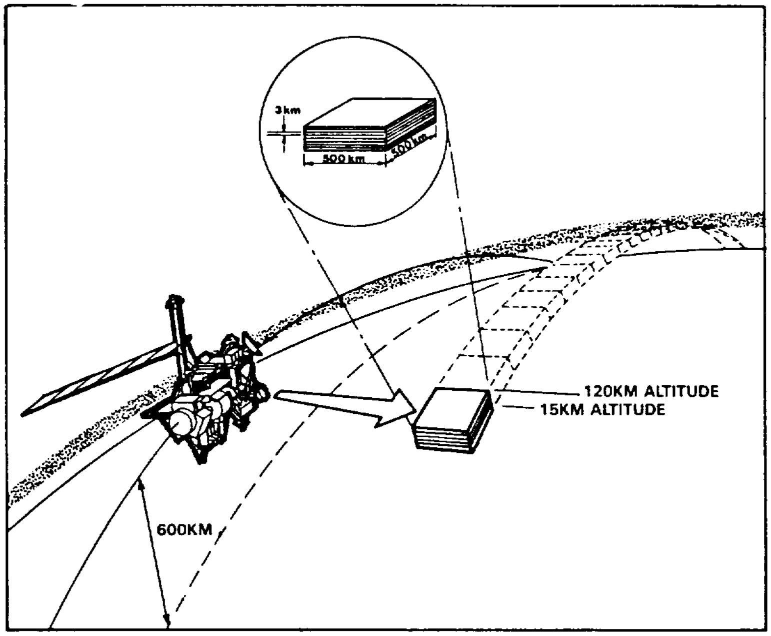


Figure 1-6. The spatial resolution requirements for the limb viewing instruments are half a scale height in the vertical (2.5 to 3 km) and 500 km in latitude.

The need for high resolution in altitude measurements requires that all of the instruments making direct measurements on the atmosphere are limb viewers, meaning that they take their measurements by looking towards the horizon rather than down at the surface. The limb viewing nature of these instruments means that they must be precisely oriented in relation to the Earth.

More specifically, the observatory must provide Earth-referenced control of instrument pointing to an accuracy of 0.1 degrees and to provide for ground determination of instrument boresight pointing to an accuracy of 0.03 degrees (3 sigma), with pointing calibration provided by the instruments. This same pointing accuracy allows wind measurements to better than 5 msec using Doppler shift techniques.

Table 1-1. Spacecraft mission parameters

Payload Complement	10 science instruments
Initial Altitude	600 km (324 nm)
Inclination	57 deg
Attitude Control	0.01 deg precision (1σ)
Size	32 ft long, 15 ft diameter (launch configuration)
Weight	Observatory 15000 lbs Total in STS 17000 lbs
Power	1.6 kW orbital average
Data Rate	32 kbps
Tape Recorders	NASA-Standard (2), 500 megabits each
Communications	512 kbps, recorder playback 32 kbps, real-time science 1 kbps, engineering 0.125, 1, 2 kbps, command
Launch Vehicle	STS
Mission Life	18 months covering 2 Northern Hemisphere winters (36-month design life)

Table 1-2. Instrument measurement requirements

Parameter	Requirement
Spatial Resolution	
Vertical	Half a scale height (2.5 to 3 km)
Latitude	500 km
Longitude Range	1000 km to zonal means

In addition to providing high resolution, the limb viewing instruments combined with the 57-degree inclination of the orbit will allow UARS to take measurements to 80 degrees latitude, covering better than 98% of the Earth's surface (Figure 1-7). The 57-degree inclination also produces a precession of the orbit plane such that all local solar times can be sampled in about 34 days. This allows resolution of diurnal atmospheric effects in a period that is short relative to seasonal effects.

Figure 1-8 shows the UARS measurements as a function of altitude. Data acquired by the total UARS system will thereby produce a global picture of the Earth's upper atmosphere. The fall launch, combined with the 18-month minimum lifetime will yield data on two Northern Hemisphere winters.

1.4 Observatory Instruments and Theoretical Investigations

There are twenty Principal Investigators (PIs) associated with UARS. Ten of these are instrument PIs. In addition to conducting

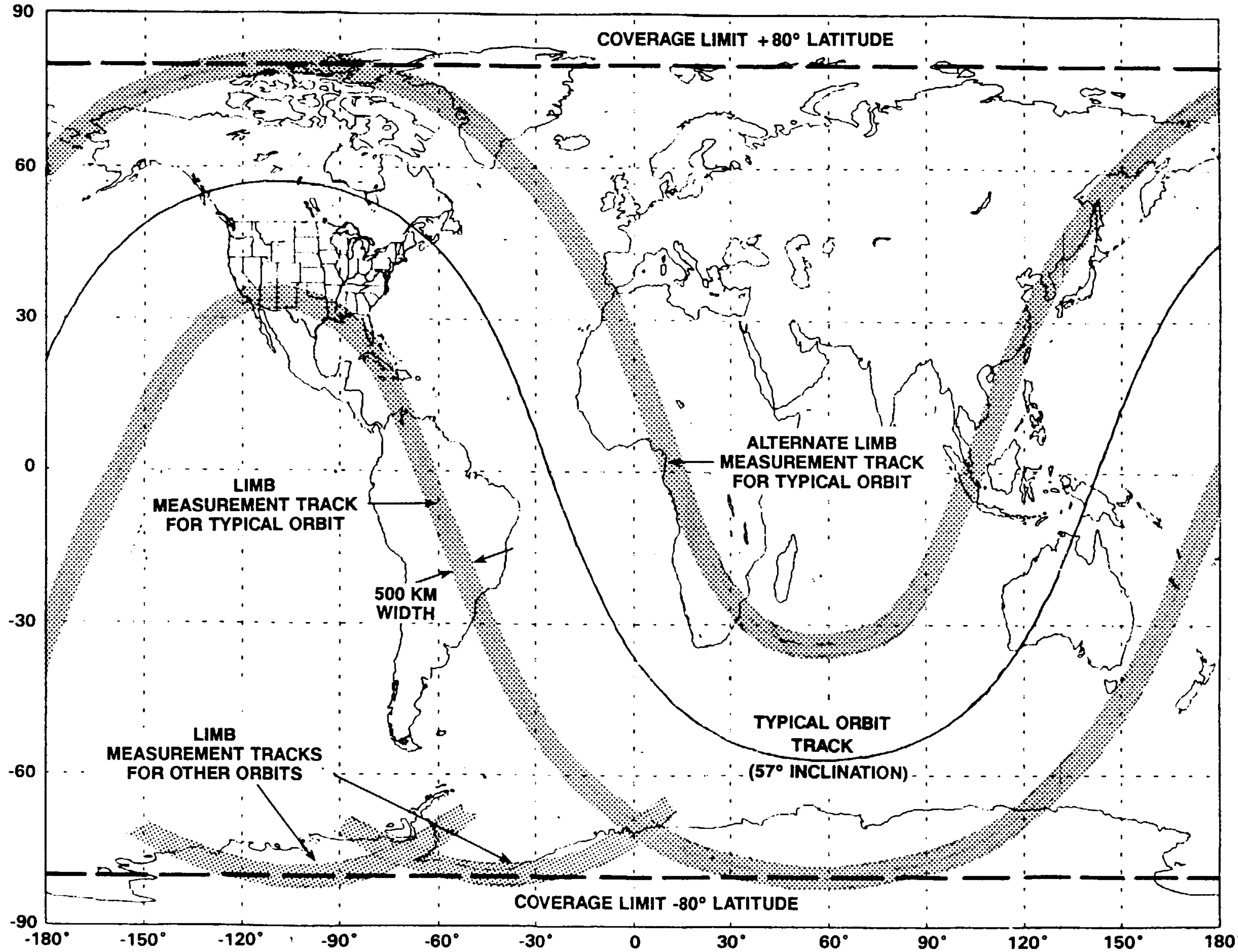


Figure 1-7. The UARS will take measurements to 80 degrees latitude north and south, covering over 98% of the Earth's surface.

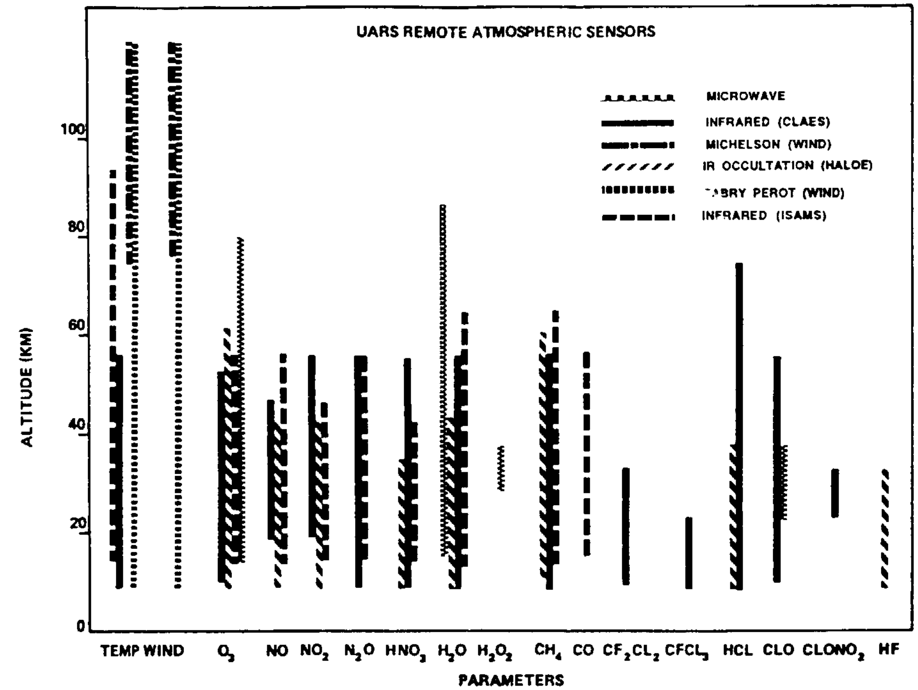


Figure 1-8. The UARS instruments will make comprehensive measurements of wind, temperature, pressure and gas species concentrations as a function of altitude, latitude, longitude and time. This chart shows the measurements as a function of altitude.

Table 1-3. The ten UARS Instruments provide a comprehensive set of atmospheric measurements

OBSERVATION	HRDI	WINDII	CLAES	ISAMS	MLS	HALOE	SUSIM	SOLSTICE	ACRIM II	PEM
WINDS	X	X								
TEMPERATURE	X	X	X	X						
PRESSURE			X	X	X	X				
GAS SPECIES CONCENTRATIONS			X	X	X	X				
SOLAR IRRADIANCE							X	X	X	
ENERGETIC PARTICLES										X

research studies along with associated Co-Investigators (Co-Is), each instrument PI is also responsible for the development and operational support of a specific UARS instrument. The remaining ten PIs, and their Co-Is, will conduct theoretical studies.

1.4.1 Instruments

The instrument complement for UARS consists of nine instruments devoted to the primary atmospheric mission plus one instrument that is using the observatory as a mission of opportunity. Table 1-3 summarizes the ten UARS instruments and the respective atmospheric measurements. Table 1-4 lists the ten UARS instruments along with their respective principle investigator and originating institution.

Table 1-4. The UARS instruments grouped by type of measurement

UARS Energy Input Measurements

Instrument	Description and Measurements	Investigator, Institution
SOLSTICE-Solar-Stellar Irradiance Comparison Experiment	• Full disk solar irradiance spectrometer incorporating stellar comparison • Solar spectral irradiance: 115-440 nm	G. J. Rottman, University of Colorado
SUSIM–Solar Ultraviolet Spectral Irradiance Monitor	• Full disk solar irradiance spectrometer incorporating onboard calibration • Solar spectral irradiance: 120-400 nm	G. E. Brueckner, Naval Research Laboratory (NRL)
PEM–Particle Environment Monitor	• X-ray, proton, and electron spectrometers • *In situ* energetic electrons and protons; remote sensing of electron energy deposition	J. D. Winningham, Southwest Research Institute

UARS Species and Temperature Measurements

Instrument	Description and Measurements	Investigator, Institution
CLAES–Cryogenic Limb Array Etalon Spectrometer	• Solid-cryogen cooled interferometer sensing atmospheric infrared emissions • T, CF_2Cl_2, $CFCl_3$, $ClONO_2$, CH_4, O_3, NO_2, N_2O, HNO_3, and H_2O	A. E. Roche, Lockheed Palo Alto Research Laboratory
ISAMS–Improved Stratospheric and Mesospheric Sounder	• Mechanically cooled radiometer sensing atmospheric infrared emissions • T, O_3, NO, NO_2, N_2O, HNO_3, H_2O, CH_4, and CO	F. W. Taylor, Oxford University
MLS–Microwave Limb Sounder	• Microwave radiometer sensing atmospheric emissions • ClO, O_3, H_2O and H_2O_2	J. W. Waters, Jet Propulsion Laboratory (JPL)
HALOE–Halogen Occultation Experiment	• Gas filter/radiometer sensing sunlight occulted by the atmosphere • HF, HCL, CH_4, NO, CO_2, H_2O, O_3, and NO_2.	J. M. Russell, NASA/Langley Research Center (LaRC)

Table 1-4. The UARS instruments grouped by type of measurement (Cont.)

UARS Wind Measurements

Instrument	Description and Measurements	Investigator, Institution
HRDI-High Resolution Doppler Imager	• Fabry-Perot spectrometer sensing atmospheric emission and scattering • Two-component wind: 10-110 km	P. B. Hays, University of Michigan
WINDII–Wind Imaging Interferometer	• Michelson interferometer sensing atmospheric emission and scattering • Two-component wind: 80-110 km	G. G. Shepherd, York University, Canada

Instrument of Opportunity

Instrument	Description and Measurements	Scientist, Institution
ACRIMII-Active Cavity Radiometer Irradiance Monitor	• Full disk solar irradiance radiometer • Continuation of solar constant measurements	R. C. Willson, Jet Propulsion Laboratory (JPL)

Collaborative Investigators

Instrument	Responsibility	Investigator, Institution
CLAES–Cryogenic Limb Array Etalon Spectrometer	Instrument science/algorithm development	J. C. Gille, National Center for Atmospheric Research (NCAR)
ISAMS–Improved Stratospheric and Mesospheric Sounder	Instrument science/algorithm development	J. M. Russell, NASA/ Langley Research Center (LaRC)

Six of the nine primary instruments are limb viewers that remotely sense atmospheric emissions, scattered light, or atmospheric absorption of sunlight in different spectral bands along the line-of-sight of the instruments. These are capable of providing altitude profiles of the measured irradiances. Data processing on the ground will translate the measurements into geophysical parameters such as atmospheric temperature, winds, and concentrations of gas species. The UARS payload also includes three instruments to measure the energy input to the Earth's atmosphere. Two of these measure solar ultra-violet energy. One measures energy from particles.

The UARS instruments are discussed in the following paragraphs.

Solar Ultraviolet Spectral Irradiance Monitor (SUSIM): Dr. G. E. Brueckner

The SUSIM instrument consists of double-dispersion grating spectrometers that measure solar spectral irradiance in the 115-440 nanometer range. In-flight calibration is provided by deuterium lamps.

Solar Stellar Irradiance Comparison Experiment (SOLSTICE): Dr. G. J. Rottman

The SOLSTICE instrument consists of small ultra-violet grating spectrometers providing a measurement of the solar irradiance over the spectral range of 115-440 nanometers. Stellar observations are used to provide reference calibration, and should permit determination of the day-to-day solar UV variations to an accuracy of 1 percent.

Particle Environment Monitor (PEM):
Dr. J. D. Winningham

The PEM instrument consists of electrostatic analyzers, solid-state particle spectrometers, and solid-state X-ray spectrometers that measure electrons in the 1 eV to 5 MeV range, protons in the 1 eV to 150 MeV range, and atmospheric X-rays in the 2 to 300 keV energy range. The objective is to determine the global input of charged-particle energy into the Earth's stratosphere, mesosphere, and thermosphere. The PEM instrument also has a 3-axis magnetometer.

Cryogenic Limb Array Etalon Spectrometer (CLAES):
Dr. A. E. Roche

The CLAES instrument consists of a high resolution etalon spectrometer operating in the 3.5 to 12.7 micron spectral range in eight measurement bands. A solid-state detector array provides a 50 km altitude profile at a view angle normal to spacecraft motion. The telescope, spectrometer, and detectors are cooled with a cryogenic system. The objectives are to obtain measurements of temperature, measurements of concentrations of the source, radical and sink species of the ozone-destructive nitrogen family, and measurements of concentrations of some of the ozone-destructive chlorine family species.

Improved Stratospheric and Mesospheric Sounder (ISAMS):
Dr. F. W. Taylor

The ISAMS instrument is an infrared radiometer that observes thermal emission from the Earth's limb. Measurements are in the 4 to 17 micron range using gas correlation spectroscopy and solid-state detectors cooled to 80 degrees Kelvin by closed cycle refrigerators. Observations are made on either side of the spacecraft, normal to the direction of flight. The objective is the measurement of the vertical distributions in the 15 to 80 km region of CO_2, H_2O, CO, NO, N_2O, NO_2, O_3, HNO_3, and CH_4 with a height resolution of 4 km and a horizontal resolution of 400 km.

Microwave Limb Sounder (MLS): Dr. J. W. Waters

The MLS instrument is a microwave radiometer that measures thermal emission from atmospheric trace species. The instrument consists of an antenna and 2 radiometers operating at 63, 183, and 205 GHz. The antenna is gimbaled to provide the altitude scan of the Earth's limb normal to observatory motion. The objective is measurement of thermal limb emission in several millimeter wavelength bands to obtain global maps of O_3, ClO, H_2O, and pressure in the 15 to 50 km region with a vertical resolution of 3 to 10 km.

Halogen Occultation Experiment (HALOE): Dr. J. M. Russell

The HALOE instrument contains a four-channel gas correlation radiometer and a four-channel filter radiometer mounted on a two-axis gimbal system. The gimbal system provides solar tracking through occultation of the sun by the Earth's atmosphere. Measurements of solar irradiation absorption are in the near infrared band from 2 to 10 microns. The objective is to measure the vertical distributions of HCl, HF, O_3, CH_4, NO, NO_2, HO, and CO over an altitude range of 10 to 65 km, with a height resolution of 2 km.

High Resolution Doppler Imager (HRDI): Dr. P. B. Hays

The HRDI instrument consists of a triple-etalon Fabry-Perot interferometer that analyzes the O_2 absorption and emission features of the atmosphere to find the temperature and vector wind fields from the upper troposphere into the thermosphere. The instrument spectral range is 400 to 800 nanometers. A two-axis gimbaled telescope allows HRDI to view the limb in orthogonal directions and scan in elevation for altitude coverage.

Wind Imaging Interferometer (WINDII):
Dr. G. C. Sheperd

The WINDII instrument consists of a field-widened Michelson interferometer that derives upper atmosphere temperatures and winds from the measurement of atmospheric emission lines in the 550 to 780 nanometer spectral range. The instrument uses a Charge Coupled Device (CCD) array detector that provides a simultaneous view of the Earth's limb in orthogonal directions over the 70 to 300 km altitude range.

Active Cavity Radiometer Irradiance Monitor (ACRIM II):
Dr. R. Willson

The ACRIM II instrument measures solar output from the far ultraviolet through far infrared wavelengths using three electrically self-calibrated, cavity detector pyrheliometers. Each detector is capable of measuring the absolute radiation with an uncertainty of 0.1 percent and resolution of 0.02 percent. The objective is the measurement of the total solar irradiance with state-of-the-art accuracy and precision. This experiment is part of a long-term program of extra-atmospheric observations to determine the magnitude and direction of variations in the output of total solar optical energy.

1.4.2 Theoretical Investigations

In addition to the investigators who have been chosen to provide flight instruments, ten investigators have been selected to provide analytical and interpretive support to the UARS program. Their contributions include chemical and dynamic modeling, meteorological and empirical modeling, and the application of these techniques to the organization and geophysical interpretation of the UARS measurements. The investigations, the Theoretical Principal Investigators and their institutions are listed in Table 1-5.

Table 1-5. Theoretical investigations

Investigator	Institution	Investigation
D.M. Cunnold	Georgia Institute of Technology	Impact of ozone change on dynamics
M.A. Geller	Goddard Space Flight Center	Dynamics
W.L. Grose	Langley Research Center	Transport, budgets, and energetics
J.R. Holton	University of Washington	Wave dynamics and transport
J. London	University of Colorado	Response to solar variations
A.J. Miller	National Oceanic and Atmospheric Administration	Meteorological interpretation
C.A. Reber	Goddard Space Flight Center	Analytic-empirical modeling
P. White	United Kingdom Meteorological Office	3-D Stratospheric Model
D. Wuebbles	Lawrence Livermore National Laboratory	Chemical, radiative, and dynamic processes
R.W. Zurek	Jet Propulsion Laboratory	Radiative-dynamic balance

Impact of Ozone Changes On Dynamics:
Dr. D. M. Cunnold

This investigation will use UARS data to develop interactively a three-dimensional photochemical-dynamic model of the stratosphere, with the goal of estimating the dynamic response of the atmosphere to chemical perturbations.

Observational Analysis of Dynamics:
Dr. M. A. Geller

This investigation will focus on the dynamics of the upper atmosphere and its interaction with the troposphere. The goal is to ascertain the effects on climate and extended range forecasting.

Stratospheric Transport Processes, Budgets of Minor Species, and Energetics: Dr. W. L. Grose

This investigation is a coordinated program of theoretical model studies combined with data analysis and interpretation. It is designed to study transport processes, budgets of trace chemicals, and energetics of the stratosphere.

Wave Dynamics and Transport of the Middle Atmosphere:
Dr. J. R. Holton

This investigation includes observational analysis and numerical modeling. The goal is to understand better the nature of the general circulation of the middle atmosphere, the role of dynamics in controlling the distribution and variability of trace species, and the nature and extent of dynamic interactions between the lower and middle atmospheres.

Response of Upper Atmosphere to Variations in Solar Activity:
Dr. J. London

This investigation emphasizes the study of the natural variability of the thermal structure and ozone concentration of the upper atmosphere with emphasis on their response to significant solar variability. It should provide definitive tests of specified mechanisms by which variations in solar activity may affect ozone amounts.

Synoptic Analysis and Dynamic Interpretation of UARS Meteorological Information: A. J. Miller

This investigation will use UARS temperature and wind data, along with operational Weather Service data, to evaluate the upper atmosphere energy budget, planetary waves, and interlayer dynamic coupling between the troposphere, stratosphere, and mesosphere.

Analytic-Empirical Modeling of Upper Atmosphere Parameters: Dr. C. A. Reber

This investigation focuses on the organization, empirical modeling, and geophysical interpretation of the data acquired from the set of instruments on the UARS. It will also acquire complementary data from other sources and provide it to the Science Team. These additional data are needed for comprehensive geophysical analysis of the UARS data.

Meteorological Processs: Dr. P. White

This investigation will combine UARS data with measurements from other sources in a numerical model of the stratosphere. The goal is to study particular features and processes in the stratosphere and the interaction of the stratosphere with the troposphere.

Chemical, Radiative, Dynamic Processes: Dr. D. Wuebbles

This investigation focuses on the chemical, radiative, and dynamic processes in the upper atmosphere using time-dependent transport kinetic models.

Radiative-Dynamic Balances in the Mesosphere:
Dr. R. W. Zurek

This investigation will analyze the zonally averaged thermal and momentum budgets for the mesosphere. By comparing the adiabatic heating term, eddy flux terms, and longer period waves, the mean meridional circulation (which is too weak to be directly observed) will be calculated as a residual of the thermal and momentum budgets.

1.4.3 Observation Requirements and Scenarios

Figure 1-9 summarizes the observation requirements of the ten instruments. This figure includes the requirements for baseline science, instrument calibration, alignment, and special observation requirements.

Figure 1-10 shows a typical mission profile for the first 18 months of operation and includes beta angle (defined as the angle between the orbit plane and the Earth-to-sun line), duration of night (defined as the length of time that the Earth blocks the sun from shining on the spacecraft), limb coverage range (the range of latitude that the limb-viewing instruments can observe), yaw-around maneuvers, and drag make-up opportunities.

Figure 1-11 shows an observation scenario for a typical 96-minute orbit. SOLSTICE will observe the sun during observatory daytime and will observe stars during darkness. SUSIM will observe the sun in daytime and calibrate its electronics during darkness. ACRIM II will observe the sun during daytime. CLAES will operate continually on a 50% duty cycle (three days active, three days inactive) to conserve it's cryogen. HALOE will observe each sunrise and sunset. HRDI and ISAMS will also operate continuously, but HRDI will pause to calibrate at the beginning of night and at the beginning of day. When the spacecraft is in sunlight, ISAMS will make observations by looking out from the shaded side of the spacecraft. When in the Earth's shadow it may also make sun-side observations. MLS, PEM and WINDII will operate continuously.

	BASELINE SCIENCE	CALIBRATION	ALIGNMENT	OTHER
SUSIM	WHENEVER SUN IN VIEW — VARIOUS	WEEKLY —60 MINUTES	INITIAL/EVERY 6 MO (TBR) — 150 MINUTES	
SOLSTICE	TWO SOLAR SCANS/DAY — 35 MINUTES TOTAL 10 STAR VIEWS/DAY (AVG) — $\geq$ 15 MINUTES CONT/VIEW	——	EVERY REV → MONTHLY — 2 MINUTES	— —
ACRIM II	WHENEVER SUN IN VIEW — $\geq$ 25 MINUTES	MONTHLY — 24 HOURS	— —	— —
HALOE	AT SUNRISE, SUNSET — 15 MINUTES	WITHIN OBSERV. SEQUENCES	PERIODIC (WITHIN OBSERV. SEQUENCE)	GRAZING ($\beta \leq 66°$)
HRDI	CONTINUOUS — DAY, NIGHT MODES	DAILY → MONTHLY — 30 MINUTES (NIGHT)	INITIAL/AS REQ'D — 26 SECONDS	TROPOSPHERIC SCAN
WINDII	CONTINUOUS —DAY, NIGHT MODES	ONCE-TWICE/WEEK — 1-3 HRS (TBR)	WEEKLY (TBR) — 60 SECONDS (TBR)	FUNCTIONAL TEST
ISAMS	CONTINUOUS — EITHER SIDE AT NIGHT	MONTHLY — 5 MINUTES* (NIGHT)	WITHIN OBSERV. SEQUENCE	— —
CLAES	CONTINUOUS FOR 3 DAYS — 50% DUTY CYCLE	CONCURRENT WITH ALIGNMENT	INITIAL/AS REQ'd — 6 SECONDS*	SUDDEN-EVENT OBSERVATION
MLS	CONTINUOUS — WEEKLY MODE CHANGE	WITHIN OBSERV. SEQUENCE	INITIAL/AS REQ'D — (TBD)	— —
PEM	CONTINUOUS	WEEKLY (AXIS, HEPS) —2 MINUTES	WITHIN OBSERV. SEQUENCES	AXIS RADIATOR BAKE-OUT

* REQUIRES ROLL OFFSET

Figure 1-9. The observation requirements for the 10 UARS instruments

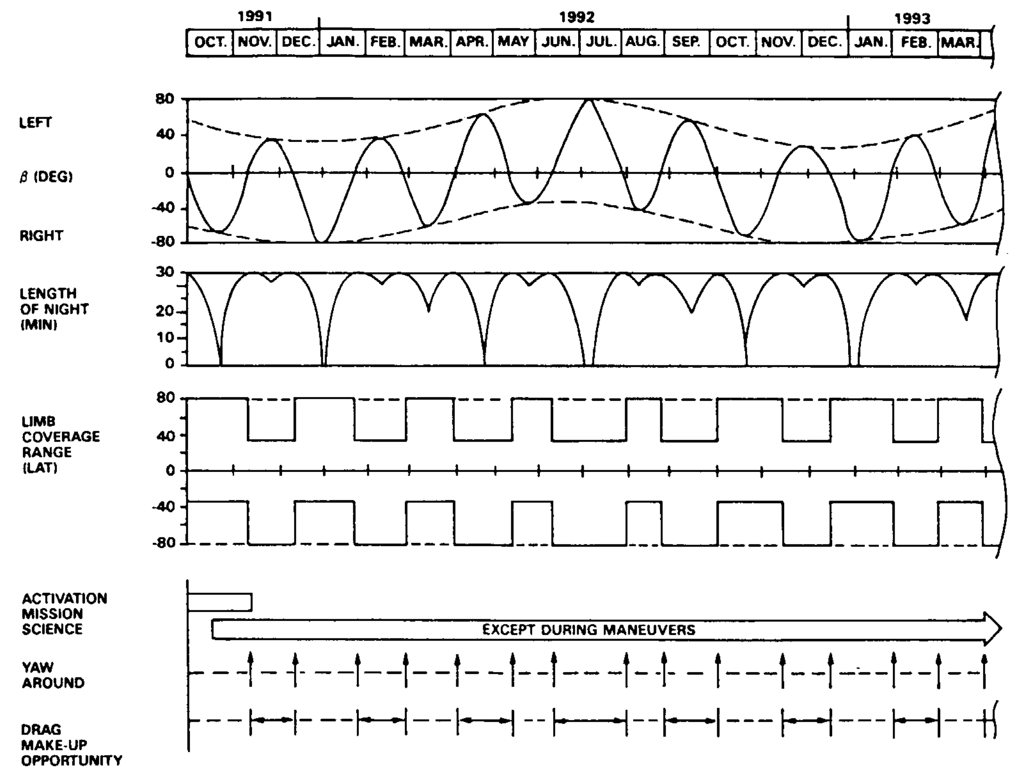


Figure 1-10. A typical mission profile for the first 18 months of operation.

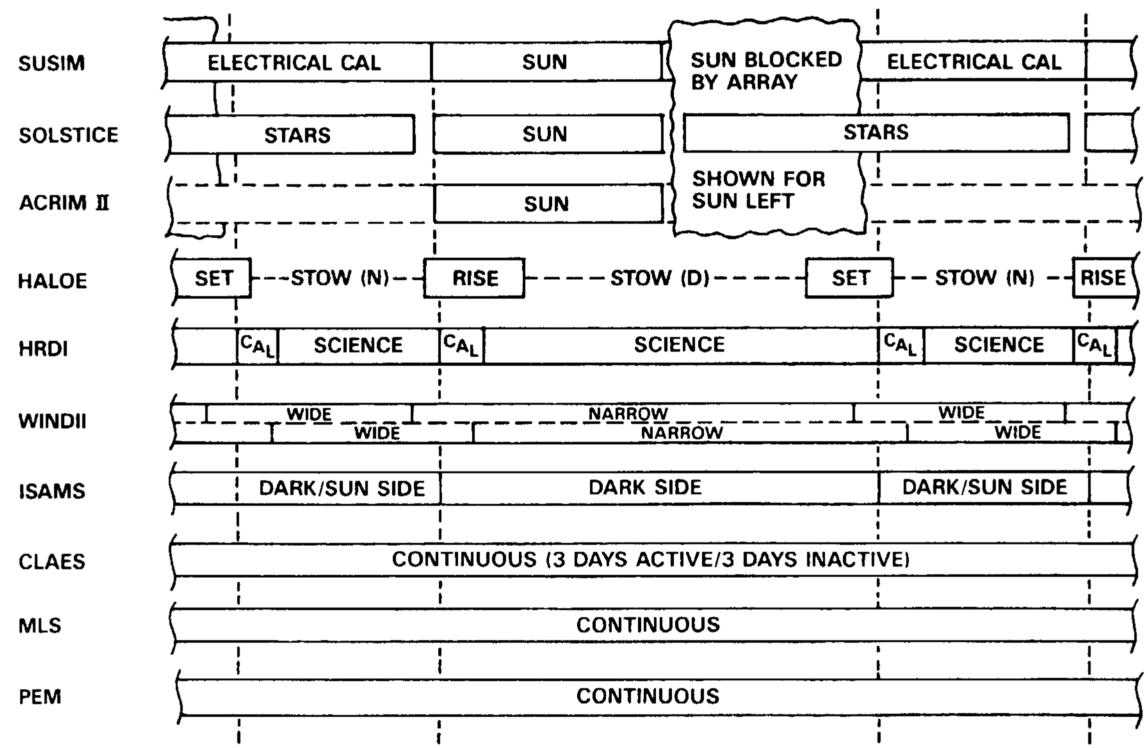


Figure 1-11. An operation scenario for a typical 96-minute orbit.

SECTION 2
THE UARS SYSTEM

Section | Page

2. The UARS System

2.1 System Summary

The UARS System includes both the flight observatory and ground-based elements consisting of both mission-unique and institutional elements. The institutional elements can be further broken down into communications elements on the one hand, and the ground system elements needed to support flight operations and data capture on the other.

The UARS observatory consists of ten science instruments, an Instrument Module (IM) including mission-unique hardware, and the Multimission Modular Spacecraft (MMS). It will provide precision pointing for the science instruments on an Earth-oriented platform, periodic routine maneuvers to maintain a favorable sun orientation, and the ability to communicate through the Space Network. Figure 2-1 shows the relationship of the UARS observatory to the major system elements. The UARS observatory with its major components is shown in Figure 2-2. Figure 2-3 shows the placement of the instruments on the spacecraft.

Communications between the observatory and the ground facilities will be provided by the Space Network S-band service. The UARS will also be compatible with the Deep Space Network (DSN) for support during emergency situations.

Flight operations will be performed through GSFC institutional mission support systems. These facilities will provide for satellite command and control, definitive orbit and attitude computations, command management, and data capture.

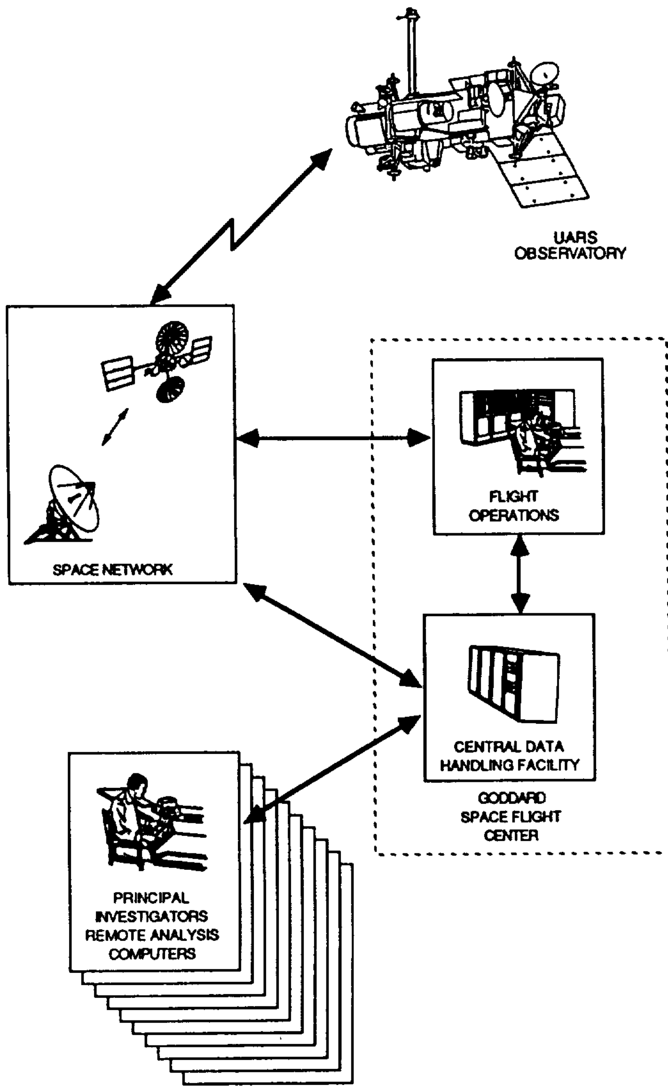


Figure 2-1. The UARS system includes both the flight observatory and ground-based elements. Communications with the observatory will normally be provided by TDRSS.

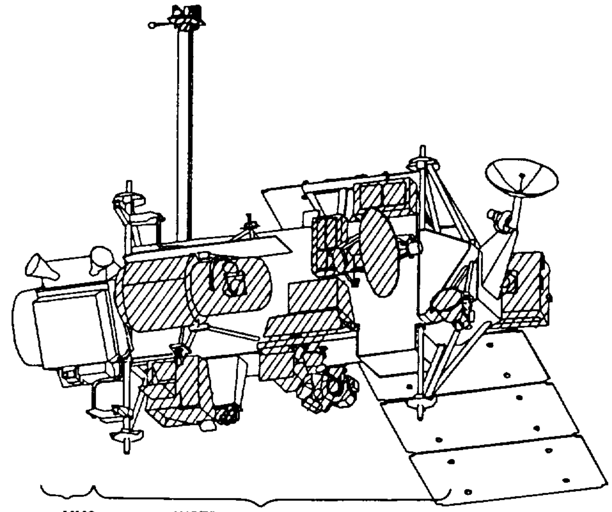


Figure 2-2. The UARS observatory consists of ten science instruments, an Instrument Module including mission-unique hardware, and a Multimission Modular Spacecraft. The observatory is approximately 32 ft long, 15 ft in diameter, and 15,000 pounds.

Instrument data processing will be accomplished in the mission-specific Central Data Handling Facility (CDHF) located at Goddard Space Flight Center. Data analysis and theoretical studies will be conducted by members of the UARS science team through use of Remote Analysis Computers (RACs) located at the Principal Investigators' (PIs) facilities. PIs will also have access to the CDHF data base archival system.

2.2 Observatory Subsystems

The UARS observatory consists of a standard Multimission Modular Spacecraft coupled to an Instrument Module that includes the ten science instruments and various mission-unique components.

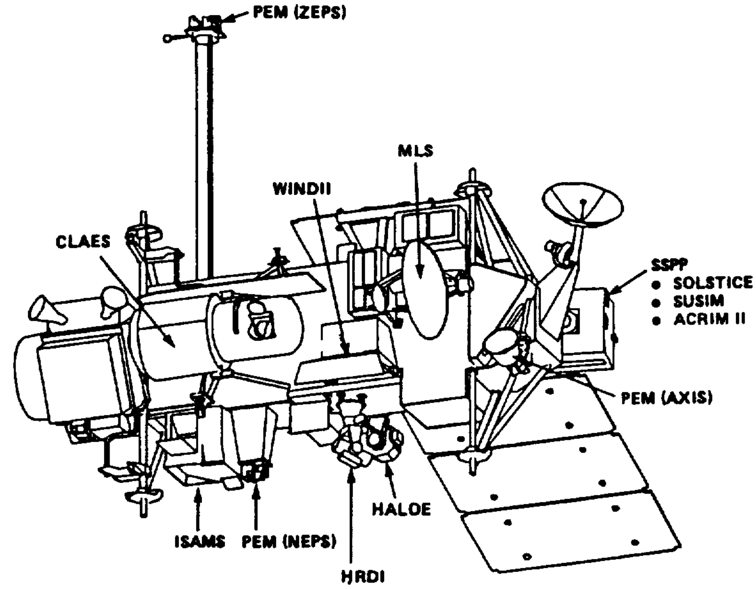


Figure 2-3. The UARS observatory showing the 10 science instruments.

The observatory uses the MMS to provide attitude control, communications and data handling, electrical power storage and regulation, propulsion, and pyrotechnic firing circuits. Mission-unique equipment includes the Instrument Module structure, a solar array, high gain and omnidirectional antennas, an RF interface box, a power switching unit, and a solar stellar pointing platform. (See Figure 2-4.)

The following paragraphs briefly describe the functional capabilities of the observatory subsystems.

Multimission Modular Spacecraft

The Multimission Modular Spacecraft is an on-orbit serviceable spacecraft bus provided by Fairchild Space Company. The MMS has a modular design, and includes both functional modules and

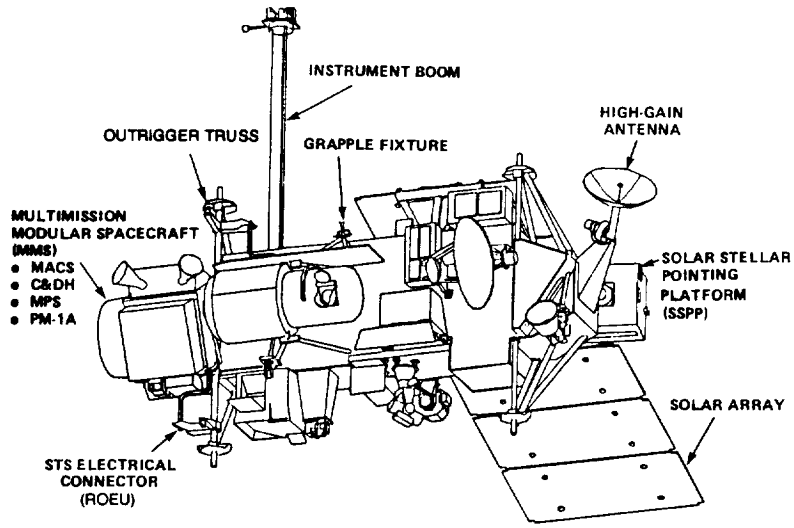


Figure 2-4. The UARS observatory showing key subsystem elements.

a modular support structure as shown in Figure 2-5. MMS modules include the Communications and Data Handling (C&DH) subsystem, the Modular Attitude Control Subsystem (MACS), the Modular Power Subsystem (MPS), the Signal Conditioning and Control Unit (SC&CU), and the Propulsion Module. The forward end of the MMS structure provides the surface for mating to the mission-unique portion of the observatory. The rear end contains the Propulsion Module. The function of each MMS module is covered in the descriptions of the individual subsystems in the following paragraphs.

Structural Subsystem

The structure is designed to accommodate instruments, mission-unique equipment, and the MMS. It provides the overall framework for supporting and positioning the instruments and for maintaining the instrument pointing and alignment. It also supports the mission-unique components and provides the me-

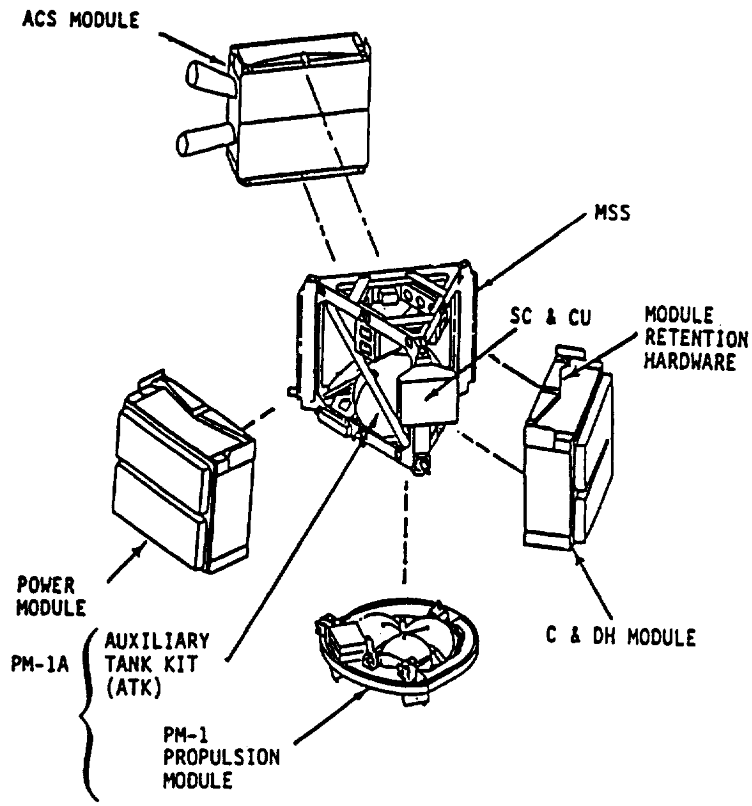


Figure 2-5. Exploded view of the Multimission Modular Spacecraft.

chanical interface to the MMS through the aluminum unified mission adapter and the mechanical interface to the STS through six outrigger trusses. The truss design of the graphite-epoxy primary structure provides a stable framework to maintain precise alignment of the critical elements of the system through mission life. The secondary structure provides mounting support for the instruments, solar array, and other mission-unique equipment. Other mechanical elements include the Zenith Energetic Particle System (ZEPS) boom, and the STS grapple fitting.

Electrical Subsystem

The electrical subsystem consists of those components designed to distribute signals, power, commands, and telemetry throughout the Instrument Module. It also includes the pyrotechnic devices used to restrain the spacecraft appendages during powered flight, and jettison them if required for an STS retrieval. The Signal Conditioning and Control Unit (SC&CU) provides a means to arm, safe, and fire the pyrotechnic devices.

Power Subsystem

This subsystem provides 1600 watts (orbit average) of electrical power for the payload instruments and other observatory systems.

The power subsystem consists of the MMS Modular Power System (MPS) and mission-unique equipment. The MPS provides power storage, power regulation, bus protection and power disconnect circuitry. The mission-unique equipment includes the solar array and electronics for power distribution and control. An auxiliary power regulator handles power demands in excess of the MPS 1200-watt capability.

The solar array is sized to provide the required power for a period of 18 months, and has a design lifetime of 36 months. The three 50-ampere-hour batteries are also designed for a 36-month orbital lifetime based on 25 percent depth of discharge per orbit. The power distribution and control system provides power switching, protection, and routing for the operation of subsystem equipment and instruments.

Attitude Determination and Control Subsystem

The MMS Modular Attitude Control Subsystem in combination with the mission-unique equipment and software will provide attitude determination and control capability during all operational phases of the mission — including separation from the STS, Earth acquisition and stabilization, calibration maneuvers and slews, and nominal Earth pointing. During normal operations, this subsystem will maintain the observatory in an Earth-oriented, three-axis controlled attitude. The MACS unit to be used on the UARS mission was used on the Solar Maximum Mission, retrieved by the STS, and is being refurbished for the UARS.

In addition to maintaining spacecraft stability, the AD&C Subsystem will perform yaw orientation maneuvers and orbit adjust maneuvers. It is capable of offset pointing, and it will provide failure detection and correction logic, as well as backup analog safe-hold control modes to maintain power and thermal-safe orientations in the event of a failure in the AD&C Subsystem.

The AD&C Subsystem also includes the MMS Propulsion Module and the onboard attitude determination software package which is implemented in the spacecraft On-board Computer (OBC). The OBC is part of the C&DH module. The MMS propulsion module is described separately.

Communications and Data Handling Subsystem

The MMS Communications and Data Handling (C&DH) module, combined with the mission-unique equipment, will provide the required tracking, communications with the ground, command execution, telemetry data acquisition and storage, generation of timing signals, and computation capability.

The radio frequency (RF) equipment is designed to be compatible with the STS, and the Deep Space Network (DSN). The telemetry equipment will be capable of simultaneously acquiring mission science and engineering data, and producing two separate telemetry data streams.

The mission-unique elements include an RF Interface Box, two omni-directional antennas, gimbal drive electronics, and a high-gain antenna system which provides the forward and return links to the TDRS, with high data rate telemetry, tracking, and command.

The MMS C&DH module includes electronics for RF communications, signal processing, command and telemetry, and related functions. It also includes two tape recorders and the On-board Computer (OBC).

The OBC is a NASA-standard spacecraft computer that provides for autonomous operation of the spacecraft. The OBC will perform functions such as stored command processing, precision attitude control computations, health and safety monitoring, absolute time code computation, and power management.

The command equipment will receive, process, and execute real-time commands as well as delayed commands from the On-board Computer. Delayed commands can be executed as a function of either time or event.

Thermal Control Subsystem

Thermal control of the UARS during STS launch and the subsequent orbital phase of the mission will be accomplished with a basically passive design augmented by electrical heaters. In addition to the heaters, this subsystem consists of blankets, paint, coatings, and temperature sensors. The Thermal Control Subsystem (TCS) also accommodates conduction and radiation interfaces with the STS orbiter in the launch phase, and controls overall structure temperatures in the orbital phase to minimize instrument pointing errors caused by thermal distortion.

Solar Stellar Pointing Platform

The Solar Stellar Pointing Platform (SSPP) is a two-axis, gimbaled system that points three instruments (SOLSTICE, SUSIM, and ACRIM II). It provides instrument pointing at the sun for solar observations during portions of each orbit. It also points these instruments at selected bright stars for SOLSTICE calibration. The SSPP subsystem includes platform sun sensors, position encoders, and the gimbal drive electronics, as well as hardware to restrain the platform during launch and relatch it for STS recovery. The gimbal drive is controlled by the OBC through dedicated drive electronics.

STS Interfaces

The STS interface equipment provides structural and electrical interconnection between the UARS and the STS. These interfaces are grouped into six hardware-oriented areas.

1. The UARS Airborne Support Equipment (UASE) consists of the electrical link between UARS and STS, the mechanical hardware needed to support the link, and the STS ground support equipment.

2. The Remotely Operated Electrical Umbilical (ROEU) connects the UARS and UASE. It provides the only electrical interface between UARS and orbiter.

3. The T-0 Umbilical provides pre-launch control and monitoring of selected UARS functions until just prior to launch. It includes hardware connections between the observatory and its ground support equipment, and separates from the STS at launch.

4. The payload retention latches provide the physical restraints to position and lock the UARS payload into the cargo bay.

5. The STS Remote Manipulator System (RMS) will deploy the UARS observatory after the STS has achieved orbit and UARS check out is complete.

6. The STS Payload Interrogator provides an RF link to establish telemetry and command capability via the orbiter.

Propulsion Subsystem

The UARS design will include the MMS hydrazine Propulsion Module (PM-1A) for orbit adjust maneuvers to maintain the required altitude. The propulsion subsystem may also be used in conjunction with magnetic torquers to unload reaction wheels. The propulsion subsystem consists of four 5 lb translational thrusters, twelve 0.2 lb attitude control thrusters, and associated tank and latch valves.

2.3 Flight Operations

2.3.1 General

UARS flight operations consist of on-orbit operations of the ten scientific instruments and supporting spacecraft subsystems as well as the ground operations required to command, control, and monitor the orbiting observatory. Each of the elements requires significant prelaunch activity to achieve operational readiness.

Flight operations will utilize GSFC institutional support facilities. These facilities will provide for command and control, orbit and attitude computation, command management, and data capture. Communications between the observatory and the ground facilities will be provided by the Space Network. The UARS will also be compatible with the Deep Space Network (DSN) for emergency communications.

A flight operations team (provided by the observatory contractor) will work with a science-oriented mission planning group and with each of the ten instrument PIs to plan and execute UARS flight operations. A mission planning group provided by GSFC will generate daily science plans and schedule necessary command sequences, based on the long-term science plan developed by the science team. (The science team includes each UARS instrument PI and is chaired by the UARS project scientist.) The Flight Operations Team (in the POCC) will implement all aspects of spacecraft subsystem operations to support the daily science plan.

The instrument investigators are responsible for generating the required instrument command sequences and maintaining instrument software. They are responsible for monitoring instrument performance from remote terminals that are linked to the GSFC ground system by voice and real-time communications.

The GSFC Mission Operations and Data Systems Directorate (MO&DSD) and the Networks Directorate will implement, maintain, and operate the necessary ground system for conducting on-orbit operations. In addition, they will provide a training simulator and mission analysis support to determine launch time, launch window, optimum orbit, orbit decay, network coverage, observatory attitude, and orbit adjust scenarios.

The observatory contractor will implement, maintain, and operate the necessary On-board Computer (OBC) Software Development and Validation Facility. In addition, the contractor will implement changes to the onboard spacecraft software as required.

2.3.2 Operation Flow

Because of the complex nature of the UARS spacecraft and of each UARS instrument, and because of the need to coordinate flight operations activities and instrument operation, UARS flight operations procedures are designed so that the measurements made by the various instruments will be coordinated through the flight operations process. The flight operations flow for the UARS program is shown in Figure 2-6.

UARS flight operations will be guided by a long-term science plan. Development of this plan is the responsibility of the science team, which includes each UARS instrument PI. The science team is chaired by the project scientist, and meets periodically. The flight operations team in the POCC will support science planning activities by serving as the spokesman for both ground system and spacecraft capabilities and constraints.

Daily science plans will be developed by a science-oriented mission-planning group, under the direction of the project scientist. The daily science plan for instrument control will contain all of the information necessary for command generation. These plans will be filed in the Command Management System (CMS) at GSFC, and will be available via telecommunications to Remote Analysis Computers (RACs) at various investigator locations for review. The CMS will also serve as the repository for planning and scheduling aid information.

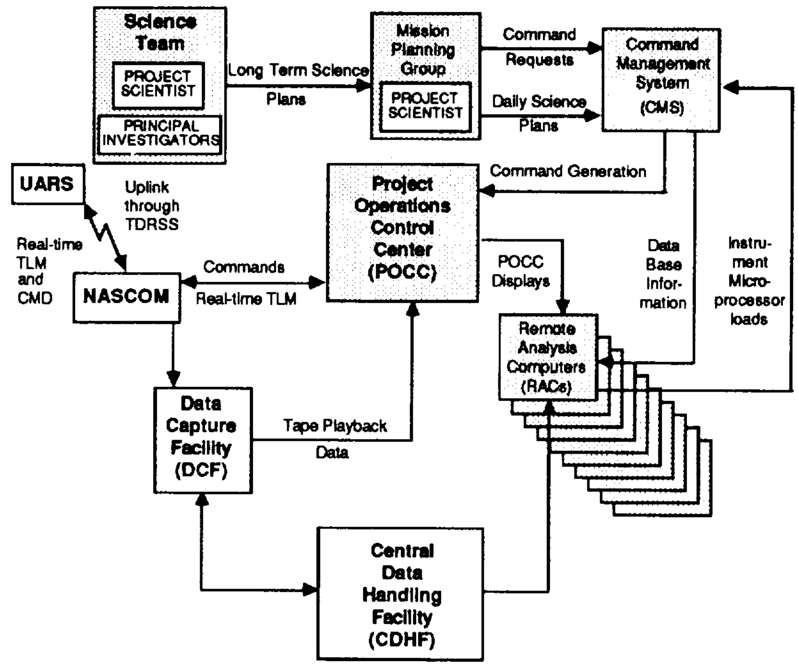


Figure 2-6. The UARS flight operations flow, with the operations elements highlighted. The ground data processing elements (DCF and CDHF) are included to show their relationship to the operational elements.

The CMS will generate commands to control UARS observatory operations according to each daily science plan, using schedule inputs from the mission planning group and command sequence information developed by instrument investigators. The CMS will perform validity and constraint checks, and will provide processed command timelines for review at GSFC and at Remote Analysis Computer locations.

The Project Operations Control Center (POCC) located at GSFC will be the focal point for on-orbit operations, and will be manned around-the-clock seven days per week by the flight operations team. The POCC will uplink commands prepared by the

CMS, and will verify successful uplink. If necessary, commands can be generated by the POCC via keyboard input. Real-time data will be displayed in the POCC for conducting on-orbit operations.

Instrument health and safety will be monitored by the flight operations team during all real-time contacts. However, each instrument investigator will monitor the overall performance of his instrument, and will be responsible for troubleshooting and instrument software maintenance. Investigators can access POCC displays via telecommunications from remote KCRT terminals. Recorded telemetry playback data will normally be available to RACs within one or two days. One quick-look tape playback will be made available on each eight-hour work shift within one hour after receipt at GSFC. Each instrument investigator will also be responsible for maintaining ground system data base information for his instrument, and for insuring that performance knowledge is properly factored into plans for ongoing operations.

2.3.3 Major System Facilities

The major elements of the system used in support of flight operation are discussed briefly in the following paragraphs.

Space Network

Communications between the ground system and UARS observatory will normally be made through the Space Network S-Band Single Access (SSA) service. Contacts between the UARS observatory and TDRS are planned for a minimum of ten minutes on every orbit. The contact will allow for simultaneous tape recorder playback at 512 kbps and real-time data transmission at 32 kbps. These contacts will normally be sufficient for OBC memory verification, and for ranging, commanding, and monitoring the performance of the observatory. Also, the SSA service will normally be used for commanding at 1 kbps. If the SSA service is not available, commanding, real-time telemetry, and

OBC dumping can be performed using the multiple-access system. An SSA emergency mode is also available if the high-gain antenna cannot be used. In addition, direct links to Deep Space Network (DSN) ground stations can be used to handle spacecraft emergency situations.

Project Operations Control Center

The POCC will be the focal point for all UARS on-orbit operations (see Figure 2-7); the flight operations team will plan and coordinate all activities necessary for achieving the mission's objectives. All commanding, processing, and displaying of downlink data for interactive control and in-depth analysis will be accomplished in this facility.

Command Management System

The CMS will be the primary interface for observatory commands. The CMS will accept observatory and instrument commands, command schedules, and instrument microprocessor loads. It will also perform validity and constraint checks, and will prepare the input for subsequent uplink by the POCC at appropriate times. The CMS facility will support science planning, and provide access to appropriate data bases for operational planning and command generation.

Flight Dynamics Facility

The FDF will provide definitive orbit determination and predicted orbit information for planning, for network scheduling, for OBC computation of orbit position, and for pointing of the high-gain antenna. It will also provide support for sensor and instrument misalignment determination, verification and evaluation of the attitude control system performance, attitude and orbit maneuver planning, definitive attitude determination, and orbit correction scenarios, as required.

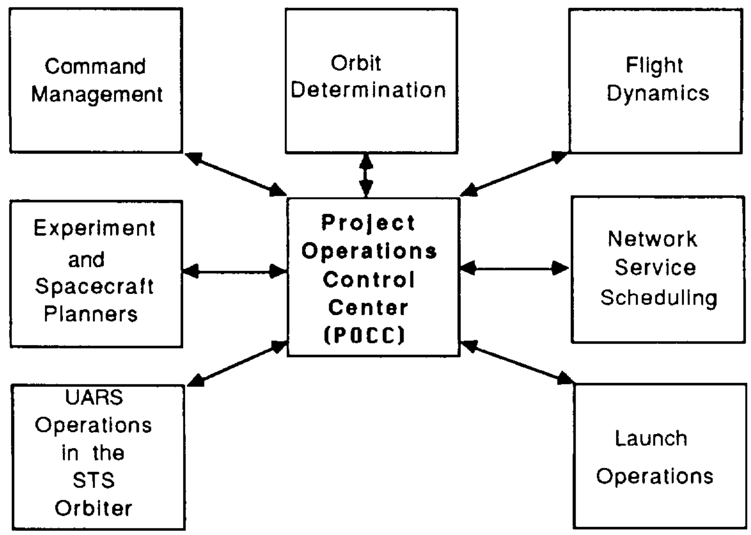


Figure 2-7. The Project Operations Control Center (POCC) located at NASA Goddard Space Flight Center will be the focal point for UARS on-orbit operations.

Data Capture Facility

The DCF will receive the downlinked tape playbacks, and real-time data when necessary, from the NASA Communications Network (NASCOM). The data will be sent routinely to the CDHF. The POCC may also request playback data from the DCF, as needed, to support the conduct of on-orbit operations — mainly in the areas of troubleshooting and anomaly investigation.

Remote POCC KCRT

The remote POCC KCRTs (consisting of keyboard and monitor) make POCC displays available at the PI sites. There are 11 Remote POCC KCRTs, one for each of the instrument investigator facilities plus one for GE. Each Remote KCRT terminal will have dial-up access to one of four lines at the POCC, thereby giving access to display pages, such as events and telemetry status, that are defined in the POCC data base.

Training Simulator

A training simulator will be used for validating the ground and flight systems, data bases and flight plan. It will also provide for flight-team training.

Software Development and Validation Facility

The SDVF will provide for development, on-orbit maintenance and update of the spacecraft computer software. Changes to the on-board software will be developed and validated with this facility before they are uplinked to the spacecraft computer. The observatory contractor is responsible for this facility.

2.3.4 Early Activation and Maneuver Requirements

2.3.4.1 Activation and Alignment

After deployment from the shuttle, an activation period of approximately thirty days is planned to permit turn-on and initial checkout of various spacecraft and instrument systems. Throughout this period, spacecraft and instrument operations will be planned and controlled from the POCC. Each instrument investigator will be scheduled to support the activation of his instrument from GSFC.

After routine operations have begun, a program of calibration and alignment analysis will be started. This program will confirm or improve on pre-launch pointing and position knowledge of various spacecraft and instrument performance parameters.

2.3.4.2 Observatory Maneuver Requirements

Spacecraft maneuvers will be required throughout the mission. In particular, a 180-degree yaw-around maneuver will be performed approximately once every 34 days. This maneuver is needed because the orbit plane will precess with respect to the sun line. The reorientation of the observatory will serve two purposes. First, it will keep both the solar array, and those instruments which measure solar irradiance, pointing at the sun. Second, it will protect those instruments that could be adversely affected by solar illumination and heating, by keeping them in the observatory's shadow where they will be shielded from the sun.

Other maneuvers will include orbit adjust maneuvers to compensate for gradual decay of the observatory orbit, and offset maneuvers to provide instrument and attitude sensor calibration.

2.4 Ground Data Processing

2.4.1 Data System

The approach for the UARS data system evolved from requirements defined by the UARS Science Working Group in 1978 and later refined by the UARS Project and Investigators. These requirements include:

1. All scientific data from the spacecraft should be processed as quickly as feasible to the level of geophysically useful data (e.g., atmospheric temperatures and gas species concentrations).

2. The instrument Principal Investigators should be responsible for developing the algorithms and for implementing and maintaining the programs used for processing data from their instruments.

3. All scientific data should be available in some form of on-line storage to all the investigators.

Implementation of these requirements has led to a system consisting of a Central Data Handling Facility (CDHF) at Goddard Space Flight Center (GSFC), minicomputer-based Remote Analysis Computers (RACs) at the investigators' sites, and a dedicated electronic communications system to connect the RACs with the CDHF (Figure 2-8).

The primary division of labor between RACs and the CDHF is that the CDHF will handle the routine processing and storage of data, while the RACs will be used for data analysis that requires human interpretation and will also be used to develop the data processing software used for the CDHF.

Playback telemetry data will be relayed from the UARS observatory by way of NASA's Tracking and Data Relay Satellite (TDRS) to the TDRS ground station at White Sands, New Mexico. From there it will go over the NASCOM network to the Data Capture Facility (DCF) at the Goddard Space Flight Center (GSFC).

The DCF performs quality checks, removes redundant data, reverses the data to time increasing order, and decommutates and formats the data. From the DCF the data will go to the Central Data Handling Facility (CDHF) at GSFC.

At the CDHF, programs developed by the investigators at their RACs and transferred to the CDHF, will be used to convert telemetry data to several levels of processed data.

The scientific investigators, located throughout the United States, and in England, France, and Canada, will have access to the data electronically, by means of RACs, located in their own laboratories. In addition to the scientific data, supporting data such as time, orbit, and attitude information will be available to the users. Figure 2-8 shows the UARS data flow.

The Principal Investigators (PIs) and their Co-investigators, will have direct access to UARS data.

The four levels of data are:

1. Level 0 — Raw telemetry from instruments (comes to the CDHF time-tagged, quality-checked, and in correct chronological sequence).

2. Level 1 — Calibrated instrument data giving the physical parameters actually measured by the sensors (e.g., atmospheric radiances in the case of the limb viewing instruments).

3. Level 2 — Geophysical parameters such as atmospheric temperature profiles, gas species concentrations, winds, or solar spectral irradiances. These are calculated from Level 1 data, and are related directly to the instrument measurement "footprint" (i.e., the character of the vertical scans is determined by a given instrument's scan rate, integration time and viewing direction, and the spacecraft orbital trajectory).

4. Level 3 — Smoothed and gridded geophysical data. Information at this level reflects the Level 2 data transformed into a common format and equally spaced along the measurement trajectory

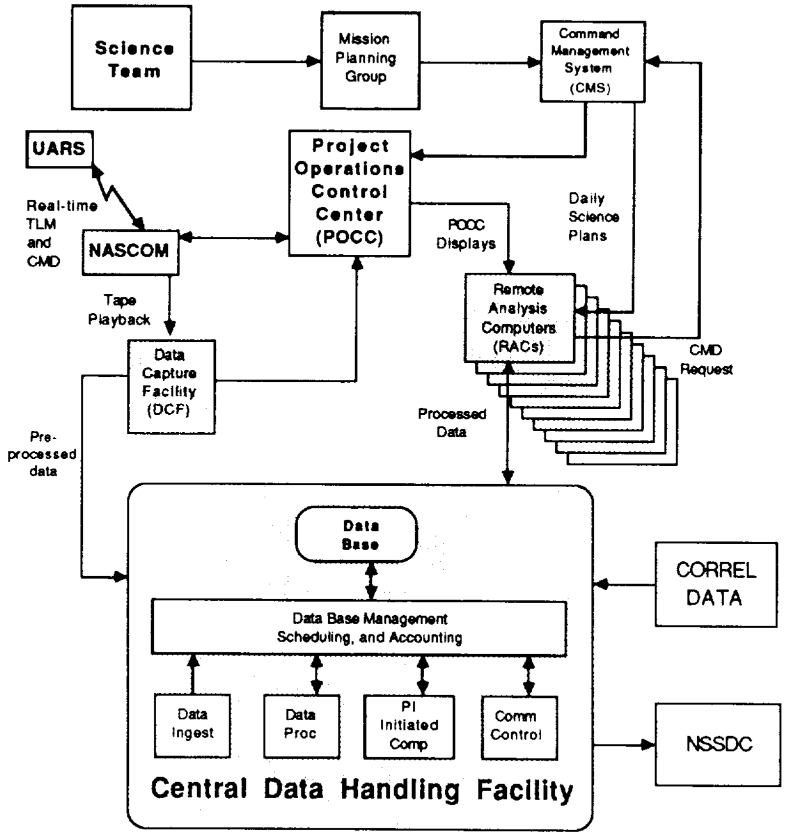


Figure 2-8. UARS Data System with data processing elements highlighted. The mission operations elements are included to show their relationship to the data system.

in time (about 1-minute centers) or latitude (several degrees). Level 3 data will also contain latitude-longitude cross sections at approximately one-half scale height altitude intervals.

The definitions of Levels 1, 2, and 3 are somewhat different for those investigations determining energy inputs to the atmosphere. These investigations will define data levels so that they are appropriate to the specific measurements being performed.

The processed data, coordinated and integrated to present a global, time-varying map of upper atmosphere conditions, will give researchers the definitive information needed to build and evaluate comprehensive models of the upper atmosphere. These models will function as tools for answering the key scientific questions regarding man's and nature's impact on the upper atmosphere.

Those PIs providing flight instruments will be responsible for developing the algorithms and for developing and maintaining the software needed for Levels 1, 2, and 3 processing. The theoretical PIs will be responsible for providing the science team with the interpretive and analytical models designed to use level 2 and 3 data. The data from UARS will be stored at CDHF for the life of the mission. These data will be cataloged to offer retrieval capabilities so that researchers can ask for and retrieve information as needed.

All investigators at the various universities and laboratories will have access to the data through remote terminals at their facilities, and all investigators will be involved in the scientific interpretation of the UARS data.

After the mission, the processed data will be stored at the National Space Science Data Center (NSSDC).

The UARS Science Team, composed of all the PIs, will be responsible for coordinating the measurement program, optimizing the scientific analysis of the data, providing appropriate theoretical models, and disseminating the results in the open scientific literature and to the National Space Science Data Center (NSSDC).

2.4.2 Facilities

Data Capture Facility

The DCF will receive and record telemetry data as described in Section 2.3.1.3 under Flight Operations. It will preprocess the data and make the data available to the Central Data Handling Facility (CDHF). The preprocessing function will consist of data capture and archival, data reversal, quality checking, and decommutation of the data into instrument and subsystem chronological records.

Central Data Handling Facility

The CDHF will be used for

1. production processing of scientific data received from the spacecraft,

2. interactive processing of a portion of the data by the Principal Investigators from their RACs to test algorithms and perform data analysis, and

3. maintenance of the UARS data base for access initially by the investigators and eventually by the scientific community at large.

To support these activities, the CDHF will have a processing speed of at least 16 million instructions per second (MIPS) and at least 32 megabytes of random access memory (RAM). The RACs at the investigator's sites are based on Digital Equipment Corporation (DEC) VAX computers, and will use the DEC VMS operating system. The initial CDHF configuration consists of a VAX 8800 computer. An additional computer and an optical disk system will be added to the CDHF in January 1989. Due to hardware and operating system compatibility, programs written on the RACs are fully transportable to and run directly on the central machine. In addition, there will be "virtual terminal" support, whereby a terminal at a RAC will appear to be signed on locally to the CDHF.

The various data sets that will be available at the CDHF include:

All Level 0 data

Levels 1, 2, and 3 data

Orbit and attitude data

Solar, stellar, and lunar ephemerides

Correlative data

System software, including the data catalog

Data processing programs and associated data tables

Most of the data will be stored on-line (e.g., on magnetic or optical disk) to facilitate quick access by users. A catalog of data, maintained in a data base management system, will permit searches of characteristics such as measurement parameter, time, instrument, and data level.

Investigator's Remote Terminals

The RACs at the investigator's sites will be used

1. to access data in the CDHF,

2. for geophysical analysis of the data, and in some cases,

3. for linking with larger computers for more complicated scientific analyses.

For the instrument investigators and collaborative investigators, the RACs will also be used to develop the software for processing data to Levels 1, 2, and 3 in the CDHF. After launch, these investigators will use their RACs for data validation and refinement of their processing software. Another RAC function is the support of flight operations by interfacing with the Command Management System at GSFC for instrument command and control and for microprocessor maintenance.

The communications between the CDHF and the RACs will use the DECnet protocol. This effectively creates a distributed data system for the UARS.

SECTION 3
THE UARS OBSERVATORY

Section **Page**

3. The UARS Observatory

The UARS observatory contains a number of subsystems in addition to the instrument payload. This section covers each of these subsystems and its individual components. Section 4 will cover the instrument payload.

Many of the subsystems consist of a combination of mission-unique equipment and specific modules of the Multimission Modular Spacecraft (MMS). The MMS modules used in the UARS observatory include the Communications and Data Handling (C&DH) subsystem, the Modular Attitude Control Subsystem (MACS), the Modular Power Subsystem (MPS), and the Propulsion Module (PM-1A). Because each of these modules will function within a larger subsystem, they are covered here as part of that larger subsystem.

The On-board Computer (OBC), for example, is part of the Communications and Data Handling subsystem, but many important functions are related to the Attitude Determination and Control subsystem. It also issues commands that control pointing of the High-Gain Antenna System, pointing of the Solar Stellar Pointing Platform (SSPP), and similarly important functions of several other subsystems. This interrelatedness precludes discussing any subsystem in isolation from the others. Each of the following sections, therefore, is centered on an individual subsystem, but each one also refers to other subsystems as appropriate.

3.1 Mechanical Subsystem

Functional Description of Subsystem

The mechanical subsystem includes the Instrument Module (IM) structure, the deployable boom for the PEM (ZEPS) instrument, the on-orbit cryogen vent system line, and the orbiter Remote Manipulator System (RMS) grapple fitting. Together these provide the framework for supporting and positioning the instruments, sensors, and the standard grapple fitting.

Functional and Design Description of Individual Components

The Instrument Module (IM) provides the overall framework for supporting and positioning the ten scientific instruments and for maintaining the alignment of the instrument optical boresights. It also provides mechanical support for the mission unique components, the mechanical interface to the MMS through the aluminum unified mission adapter, and the mechanical interface to the orbiter via six outrigger trusses.

The primary structure of the Instrument Module is a truss-type torque-box (shown in Figure 3-1). The torque-box is constructed from graphite-epoxy tubes with titanium end fittings connected by titanium cluster fittings. The outriggers and forward truss structure are made of titanium.

The secondary structure (shown in Figure 3-2) includes six aluminum honeycomb equipment benches, one graphite-epoxy honeycomb secondary optical bench, instrument mounting links, the solar array truss, and all bracketry and connecting hardware that connect to the primary structure. Two of the equipment benches are mounted to the IM using kinematic mount assemblies. The remaining benches are mounted with aluminum links which provide the kinematic attachment.

Five of the instruments (HRDI interferometer and telescope, ISAMS, MLS, PEM-AXIS, WINDII) are mounted with kinematic mounts. The remaining instruments are mounted directly to the primary structure. Each instrument incorporates an optical reference cube which is aligned with the instrument electro-optical axis or boresight. The instruments are mounted and aligned by aligning the instrument optical cubes with the master reference cube on the unified mission adapter. The alignment of this master reference cube, in turn, is measured relative to the master optical reference cube mounted on the Modular Attitude Control Subsystem module.

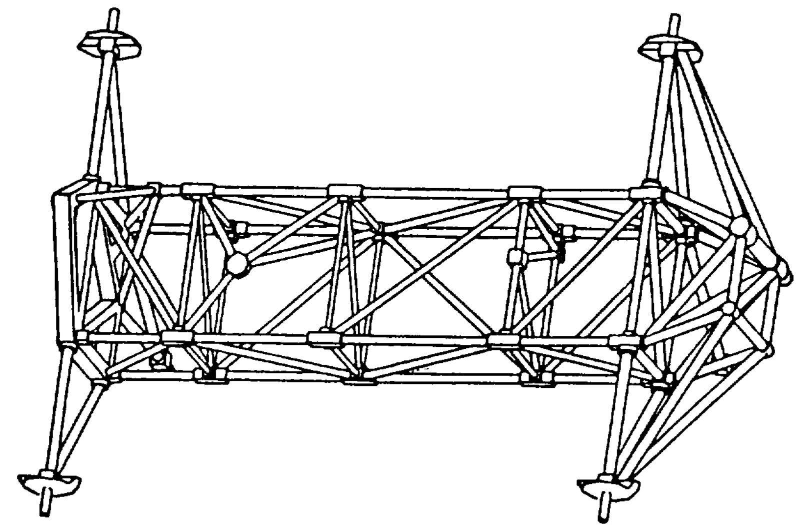


Figure 3-1. The UARS Instrument Module Primary Structure

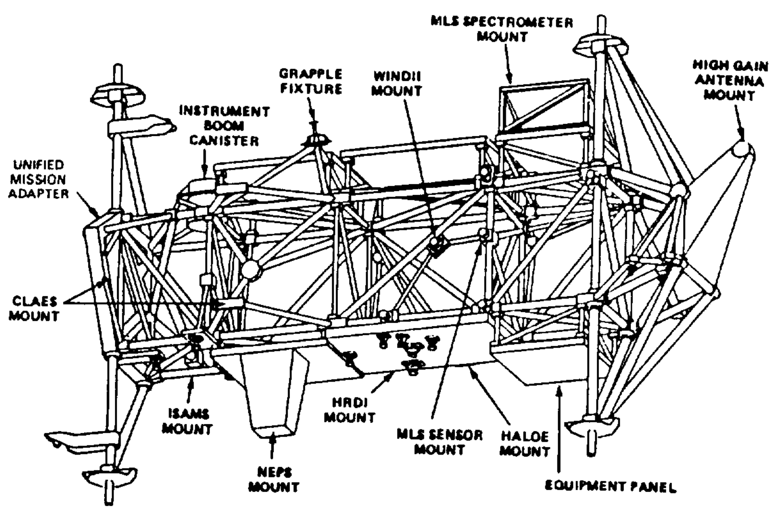


Figure 3-2. The UARS Instrument Module Secondary Structure attached to Primary Structure

Instruments mounted on the SSPP are aligned with respect to the SSPP reference cube. As with the instrument reference cube, this is aligned relative to the IM reference cube.

The unified mission adapter provides the mechanical interface between the instrument module and the MMS. This structure employs a riveted aluminum box-beam design. It provides three attachment points for the MMS through blind-mate floating-nut assemblies.

The deployable ZEPS (Zenith Energetic Particle System) boom provides support and positioning for some of the sensors that are part of the Particle Environment Monitor instrument.

The ZEPS boom is a truss of three 15-foot long glass-epoxy longerons. These are spaced as an equilateral triangle by battens and shear-stiffened by diagonal members between adjacent batten stations. The electrical harness is divided into three bundles, each of which is laced to a longeron. For stowage, the longerons are formed into three interlaced helices fitting inside a canister. The instrument mounting plate is secured by latches to the canister for launch and recovery. The energy for deployment is stored in the coiled longerons. Redundant DC motors regulate the deployment and retraction of the ZEPS through a lanyard attached to the instrument mounting base plate.

The RMS grapple fitting is located on the Instrument Module. It is a standard fitting for the STS Remote Manipulator System for deployment and recovery operations, and it is required for UARS deployment by the STS RMS system. The RMS uses the standard end effector to latch the Instrument Module grapple fitting for deployment operations and can also be used for recovery operations. The MMS also carries a standard grapple fitting.

Weight Summary

The UARS observatory weight summary is listed in Table 3-1. The observatory launch weight is approximately 15000 pounds. The total payload weight in the shuttle bay (including airborne support equipment) is 17000 pounds.

3.2 Electrical Subsystem

Functional Description of Subsystem

The electrical subsystem consists of those components designed to distribute signals, power, commands, and telemetry throughout the Instrument Module. It also includes the pyrotechnic devices used for deployment and jettison.

Functional and Design Description of Individual Components

The electrical subsystem block diagram for the UARS observatory is shown in Figure 3-3. The components of this subsystem include the following:

The Power Switching Unit (PSU) contains the switching and fusing for bus power to the IM. The PSU provides inhibits and monitoring for appendage deployment functions that are non-pyro initiated.

The Pyro Repeater Module (PRM) provides a safety ground where the wiring for the electro-explosive devices crosses a mechanical interface. The safety ground protects against accidental firing of the pyros for the solar array jettison and SOLSTICE door.

The In-Flight Disconnect (IFD) provides for harness separation if the solar array is jettisoned.

Table 3-1. UARS Observatory Weight Summary

Description	Current Weight (lbs)	
PAYLOAD INSTRUMENTS	5021.8	
ACRIM II		51.9
CLAES		2661.7
HALOE		204.1
HRDI		347.5
ISAMS		385.0
MLS		626.0
PEM		199.2
SOLSTICE		40.5
SUSIM		237.0
WINDII		268.9
SPACECRAFT BUS	5613.9	
Attitude Determination & Control		71.6
Communications & Data Handling		150.9
Electrical Integration		592.4
Electrical Power		589.6
Environmental		275.5
GFE Instrument Mounts		181.0
SSPP		324.6
Structure		3428.1
TOTAL INSTRUMENT MODULE	10635.7	
MMS (with fuel)	2497.6	
Interface Items To S/C	36.0	
TOTAL ORBIT WEIGHT (with fuel)	13169.2	
Interface Items On Shuttle	80.0	
UARS Airborne Support Equipment	1571.0	
LAUNCH WEIGHT	14820.2	
MAX LAUNCH WEIGHT	17000.0	

Current weights are estimated, from UARS interim mass properties status report, 13 March 1987.

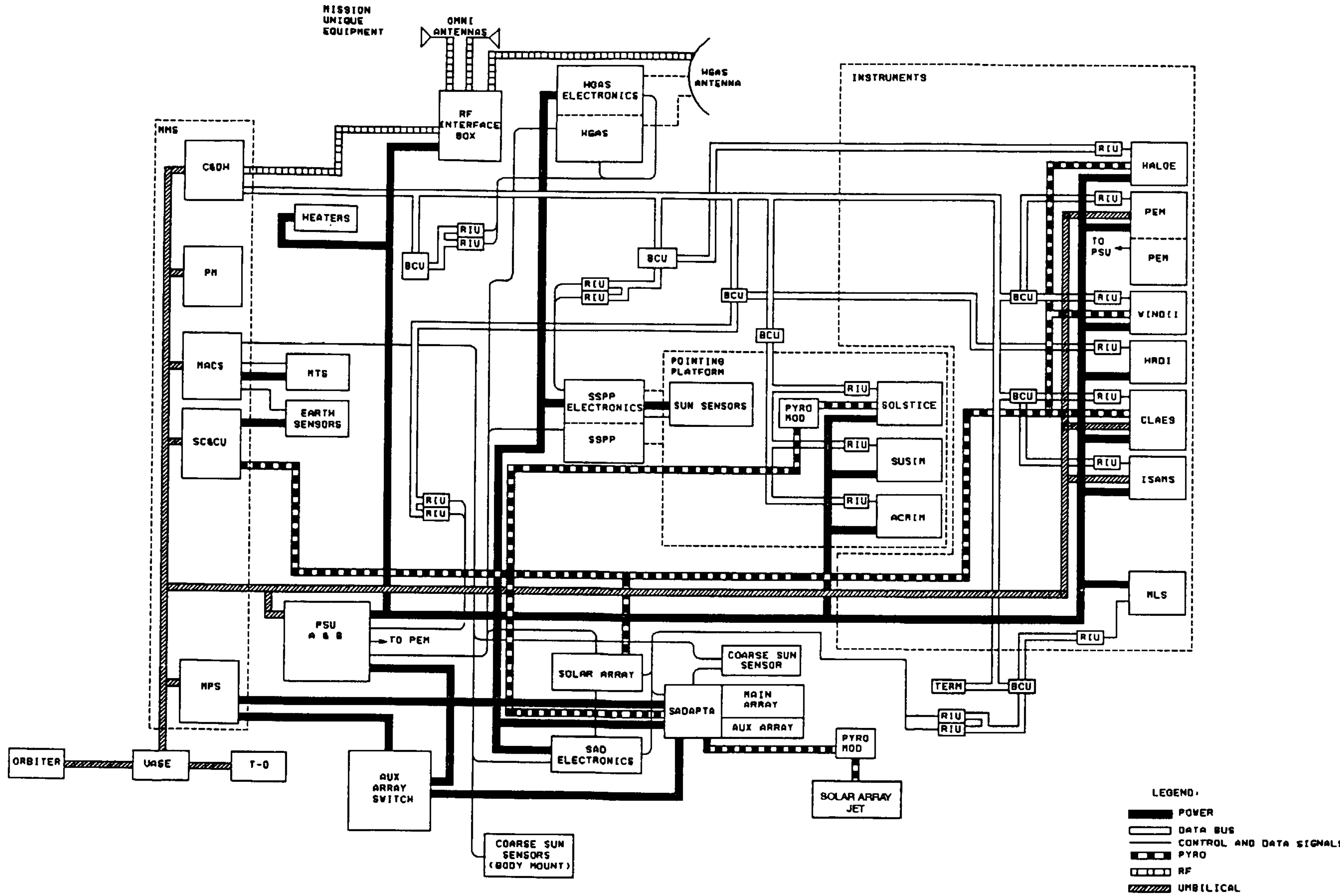


Figure 3-3. Electrical Subsystem Block Diagram

Harnessing includes all wiring to interconnect the electrical components for distribution of power, signals, commands, and telemetry.

Electro-Explosive Devices (EEDs) and Ordnance Activated Devices (OADs) are used for appendage deployment and jettison functions. All mission unique hardware pyros are NASA-standard initiators (NSIs).

The Signal Conditioning and Control Unit (SC&CU) provides the electrical inhibits and the monitoring for the pyro circuits. It also controls the MMS structure heaters.

The Remotely-Operated Electrical Umbilical (ROEU) provides the electrical interface to the STS.

3.3 Power Subsystem

Functional Description of Subsystem

The power subsystem is designed to provide an average of 1600 watts of electrical power for the UARS observatory instruments and subsystems. The six-panel solar array is sized to provide sufficient power for a period of 18 months with a design lifetime of 36 months. The three 50-ampere-hour batteries are similarly designed for a 36-month orbital lifetime based on 25-percent depth of discharge per orbit.

Functional and Design Description of Individual Components

The power subsystem consists of the MMS Modular Power Subsystem (MPS), a six-panel solar array, an Auxiliary Array Switch (AAS) regulator, a Solar Array Drive and Deployment Electronics (SADDE) module, Solar Array Retention, Deployment, and Jettison (SARDJ) parts, and a Solar Array Drive and Power Transfer Assembly (SADAPTA). The UARS power subsystem block diagram is shown in Figure 3-4.

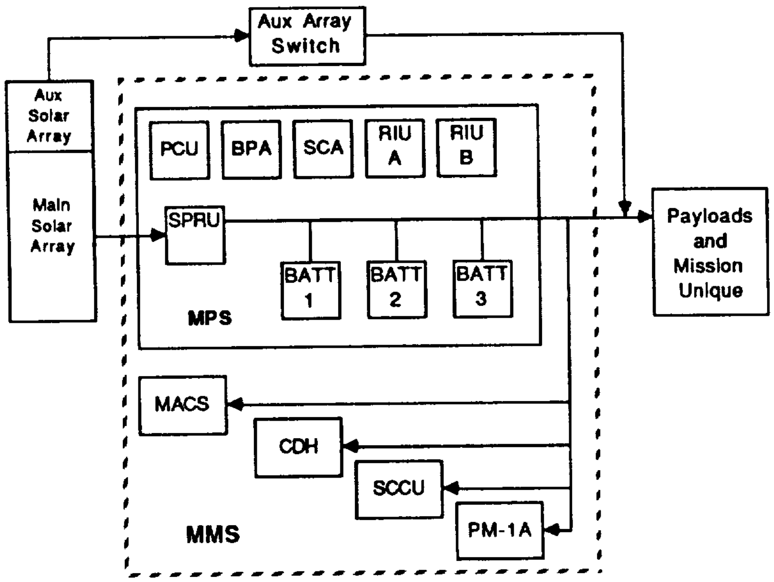


Figure 3-4. UARS Power Subsystem Block Diagram

The MMS Modular Power Subsystem (MPS) contains the following items:

Standard Power Regulator Unit (SPRU) — Controls bus voltage and battery charging. The SPRU accepts unregulated DC power from the solar array, transforms this energy from one voltage level to another, supplies the load bus requirements and controls battery charge currents.

Bus Protection Assembly — Provides redundant fusing for internal MPS loads.

Batteries and associated control, disconnect, and sensing hardware — The three 50-ampere-hour batteries provide power during periods of Earth shadow, and supplement solar array power during periods of peak load.

Power Disconnect Hardware — Consists of a group of power relays that are used to deactivate the spacecraft during ground test and prelaunch operations.

The Solar Array size is determined by the power demand through the mission life and by the orbit beta angles (defined as the angle between the orbit plane and the Earth-to-sun line). The orbit-average power requirement for UARS is 1600 watts for the first 18 months of orbital operations in the beta angle range of 0 degrees to 70 degrees. The available power will vary as a function of degradation rates and as a function of orbit parameters such as beta angle. The six solar array panels consist of silicon solar cells mounted on aluminum honeycomb substrates. Each panel is 1.25 inches thick and 128 inches long. The first panel is 63.5 inches wide; the outer five panels are 60 inches wide. The deployed solar array measures 128 x 364 inches (10.7 x 30.3 feet). The solar array cell circuits are divided between a main array and an auxiliary array. The main array feeds power to the Modular Power Subsystem. The auxiliary array feeds power to the Auxiliary Array Switch.

The Auxiliary Array Switch (AAS) contains a regulator that controls the auxiliary array power as a function of Instrument Module load current. Additional hardware in the AAS includes power disconnect relays, isolation diodes, relay drivers, current sensors, command/telemetry circuits, DC/DC converters, and test interfaces.

__The Solar Array Drive and Deployment Electronics (SADDE)__ module provides drive and rate control of the solar array drive motor.

__The Solar Array Drive (SAD)__ maintains the solar array pointing at the sun, while the observatory maintains its Earth orientation. The SAD can rotate in either direction to provide the capability to track the sun while the observatory is flying either forwards or backwards.

During launch, the observatory power is essentially off, except for approximately 16 watts of keep-alive power for the CLAES, ISAMS, PEM instruments and the FHST shutters. The UARS power budget showing orbit-average power demand is shown in Table 3-2.

3.4 Attitude Determination and Control Subsystem

Functional Description of Subsystem

Attitude control of the UARS observatory will be performed by the combination of the MMS Modular Attitude Control Subsystem (MACS), the Earth Sensor Assembly Module (ESAM), the PM-1A propulsion module, and the On-board Computer (OBC) of the Communications and Data Handling (C&DH) module. The Attitude Determination and Control Subsystem (AD&CS) will provide attitude determination and control capability during all operational phases of the mission - including separation, Earth-acquisition and stabilization, calibration maneuvers and slews, and nominal Earth-pointing. A block diagram of the AD&CS is shown in Figure 3-5.

More specifically, the AD&CS is designed to:

Perform precision attitude determination to within 60 arc-sec per axis (3 sigma),

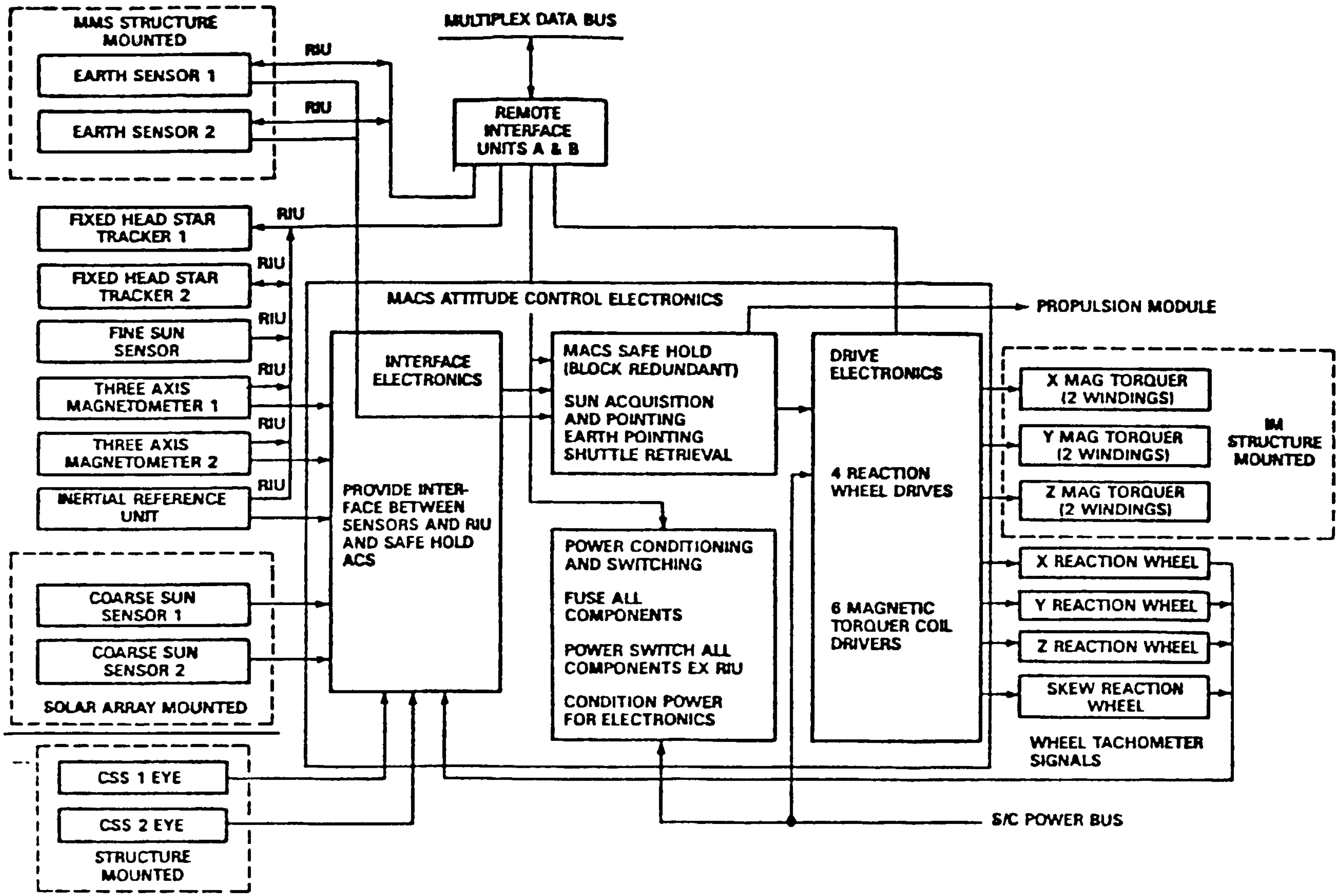


Figure 3-5. Block Diagram for Attitude Determination & Control Subsystem

Table 3-2. UARS Power Budget

Component	Orbit Average Power Demand (watts)	
Instruments (total)	776.7	
ACRIM II		5.2
CLAES		27.1
HALOE		133.5
HRDI		109.4
ISAMS		152.3
MLS		168.7
PEM		79.5
SOLSTICE		7.7
SUSIM		20.8
WINDII		72.5
MMS (total)	431.0	
MACS		149.0
C&DH		137.0
MPS		115.0
SC&CU		13.0
PM-1A		12.0
PM Heaters		5.0
Mission Unique (total)	289.8	
RIU (14 active; 4 standby)		63.0
SSPP Control Elect. & Mtrs		26.7
SSPP PSS		1.6
SAD Control Elect. & Mtrs		15.0
HGA Gimbal/Elect.		26.2
ESAM Elect. (2)		19.0
ESAM Heaters		5.0
Magnetic Torquers(3)		2.3
PSU A (Active)		13.0
PSU B (Standby)		3.0
AAS		15.0
Thermal		100.0
Total Demand	1497.5	
Power Availability	1600.0	
Power Margin	102.5	

UARS Interim Power Status Report 22 March 1987.

- Perform precision attitude control to within 108 arc-sec per axis (3 sigma),
- Maintain spacecraft stability,
- Perform 180 degree yaw-around maneuvers,
- Provide offset pointing capabilities,
- Perform orbit adjust maneuvers,
- Provide failure detection and correction logic such that no single-point failure can cause loss of attitude control,
- Provide backup analog safehold control modes to maintain power and thermal-safe orientations in the event of loss of precision attitude control.

During normal operations, this subsystem will maintain the observatory in an Earth-oriented, three-axis controlled attitude using the OBC. In the event of loss of precision attitude control, the subsystem will go to one (preselected by command) of several safehold modes to maintain the observatory in a safe attitude. These are Earth-pointing mode (near normal attitude), sun-pointing mode (aft end of spacecraft pointed at the Sun), and inertial mode (holds the inertial attitude that the spacecraft was in when going into the safehold mode). These safehold modes do not use the OBC.

Functional and Design Description of Individual Components

The AD&C subsystem consists of the following components:

MMS Modular Attitude Control System (MACS):
- Inertial Reference Unit (IRU)
- Fixed-Head Star Trackers (FHSTs)
- Fine Sun Sensor (FSS)
- Reaction Wheels
- Attitude Control Electronics (ACE)
- Three-Axis Magnetometers (TAMs)

MMS Propulsion Module with auxiliary tank kit (PM-1A)

Mission Unique Items:
- Coarse Sun Sensor (CSS) assembly
- Earth Sensor Assembly Module (ESAM)
- Magnetic Torquers
- Related flight software resident in the on-board computer.

The Inertial Reference Unit (IRU) contains three two-degrees-of-freedom gyros operating in a strapdown mode. The gyros are oriented such that redundant measurements are provided along three orthogonal axes. The digital output for each gyro channel represents a rotation about the gyro input axis. In addition to the precision digital output, the IRU generates analog signals proportional to angular rate. The IRU can operate in either a low-rate mode or a high-rate mode.

The Fixed-Head Star Trackers (FHSTs) provide absolute real-time attitude knowledge by acquiring and tracking reference stars. The FHST and IRU work along with the Earth Sensor Assembly Module and the MACS fine sun sensor to provide pointing and knowledge capabilities for the UARS observatory.

The Fine Sun Sensor (FSS) has a 64-degree square field of view. It provides two-axis analog and digital sun position data.

The Reaction Wheels will be used to perform attitude changes, provide stability, and manage momentum. Each wheel consists of an AC motor that can store angular momentum. They have a relatively constant torque-speed curve and contain a tachometer. Four wheels are provided, three mounted orthogonally and one skewed. The skewed wheel can replace any of the orthogonal wheels in the event of a failure. In normal operation the skewed wheel is operated at a fixed-speed to bias the other three wheels away from the zero-speed condition, thereby eliminating stiction effects on spacecraft pointing and maximizing bearing life.

The Attitude Control Electronics (ACE) include the electronics that drive the reaction wheels and the magnetic torquers. Also included are the safehold electronics. These can perform the analog functions needed to maintain the spacecraft in a safe attitude without the On-Board Computer. Other components of the ACE are the sensor interface electronics, and actuator drive electronics control logic and timing.

The Three-Axis Magnetometer (TAM) is a flux-gate magnetometer. It outputs three analog signals that are proportional to the magnetic field components along the TAM's input axes. The magnetometer's measurement of the Earth's field is used for magnetic unloading of the reaction wheels in both normal and safehold operation.

The MMS Propulsion Module, PM-1A, will provide the control torques and velocity increments necessary to satisfy the attitude and orbit adjust requirements. The PM-1A is a single-stage blowdown, monopropellant hydrazine propulsion system, with propellant and pressurant stored within four pressure vessels, one of which is an auxiliary tank. Four rocket engine modules provide functionally-redundant control torques using the 0.2-pound-force thrusters. They also supply the forces required to change observatory velocity using 5-pound-force thrusters.

The Coarse Sun Sensor (CSS) assembly consists of three two-axis analog sun sensors. Two are mounted on the solar array, one on the instrument module. The assembly provides sun position information that is used for the Solar Array Drive closed loop mode and for the AD&CS sun-pointing safehold mode. These sensors provide full sky coverage.

The Earth Sensor Assembly Module (ESAM) consists of two Earth sensor assemblies mounted on the MMS. Each Earth Sensor Assembly consists of a two-axis horizon scanner which provides pitch and roll attitude error information for initial acquisition, Earth-pointing safehold mode, and attitude monitoring required by the failure detection and correction software.

The Magnetic Torquer Subsystem (MTS) provides reaction wheel momentum unloading. The three Magnetic Torquers are mounted orthogonally on the Instrument Module. Each torquer consists of two identical coils wound on a ferromagnetic rod and encapsulated with a protective covering. A controlled current passing through the coils develops the desired magnetic dipole moment of up to 500,000 pole-cm in each axis.

3.5 Communications and Data Handling

Functional Description of Subsystem

The Communications and Data Handling (C&DH) subsystem provides RF communications with the ground, command control of all spacecraft and instrument functions, acquisition and storage of science and housekeeping data, and a centralized computation capability for a number of on-board functions.

Communications with UARS will normally be through the Space Network's Tracking and Data Relay Satellite, using a mission-unique steerable high-gain antenna. The radio-frequency equipment uses S-band for compatibility with TDRS, the STS, and existing ground stations. The UARS telemetry data rate will be 32 kbps with a tape recorder playback rate of 512 kbps.

Functional and Design Description of Individual Components

The C&DH subsystem consists of the following components:

MMS Communications and Data Handling module (All components are redundant):
- Central Unit (CU)
- Standard Computer Interface Units (STINTs)
- Remote Interface Unit (RIU)
- Expander Unit (EU)
- Bus Coupling Unit (BCU)
- Pre-Modulator Processor (PMP) (dual PMP in single housing)
- On-board Computer (OBC)
- NASA-standard tape recorders
- S-band Transponder
- Power Control Unit (PCU) (dual PCU in single housing)
- Multiplex Data Bus

Mission Unique Items:
- High-Gain Antenna Subsystem (HGAS)
- Omnidirectional antenna (two omni-antennas provide nearly full spherical coverage)
- RF Interface Box (RFIB)

The C&DH subsystem block diagram is shown in Figure 3-6.

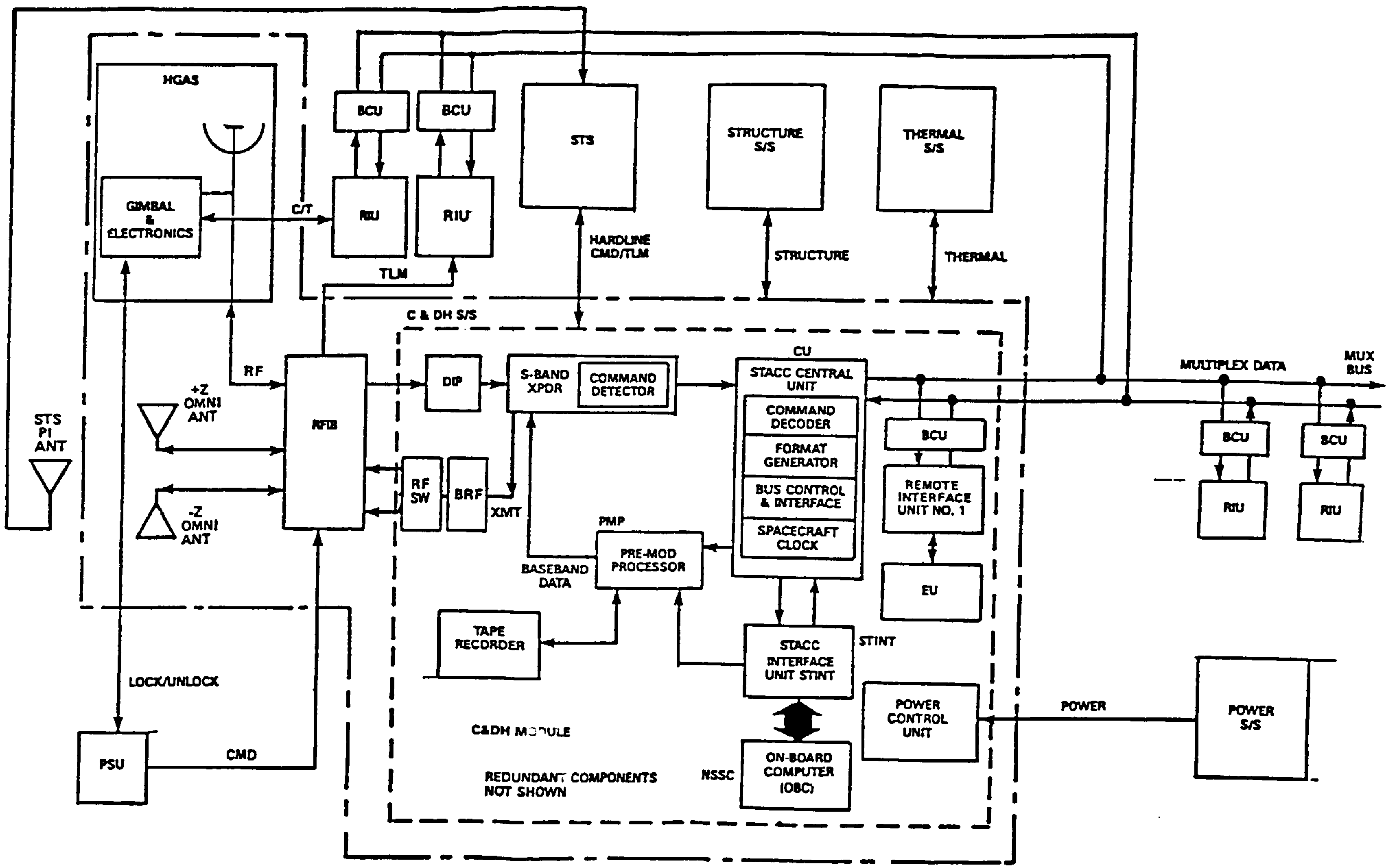


Figure 3-6. Block Diagram for the Communications and Data Handling Subsystem

The Central Unit (CU) contains a high-speed microprocessor that manages collection and transmission of telemetry, distributes commands, and provides timing signals to all observatory elements, including the OBC.

Each Standard Computer Interface Unit (STINT) serves as the input and output interface for one OBC. Each STINT is cross strapped to the redundant CUs and PMPs.

Remote Interface Units (RIUs) and Expander Units (EUs) are used for telemetry collection, and for command and timing signal distribution. The RIUs and EUs also provide signal ground isolation between the various subsystems and instruments.

Bus coupling units (BCUs) provide connection between the RIUs and the multiplex data bus.

The Pre-Modulator Processors (PMPs) contain switching circuitry that provides selection of the data transmission mode. Combinations of real-time data and tape recorder playback or real-time data and OBC memory data can be selected for transmission.

The On-board Computer (OBC) performs several functions. It stores commands, issues stored commands, implements the ACS, controls battery state of charge, controls HGAS and SSPP pointing, supports instrument operations, and monitors telemetry for out-of-limit conditions.

The redundant NASA-standard tape recorders can record up to 450 megabits each. The recorders are used to store instrument data and spacecraft telemetry for playback through the Space Network

The S-band Transponder provides redundant receivers for reception of commands from the ground. It also contains redundant 5-watt RF amplifiers for transmission of telemetry data and coherent range and range rate information.

Power Control Units (PCUs) contain the OBC power supply. They also protect the various C&DH subsystem elements against power bus overload.

The Diplexers and Band Reject Filters (BRFs) provide RF isolation between transmitters and receivers that are contained within the transponders. They also prevent out-of-band RF emissions.

The UARS antenna complement consists of the HGAS and a pair of omni-antennas. The HGAS is a two-axis gimbal-driven, parabolic antenna mounted on the forward truss structure. It operates at S-band using TDRS S-band Multiple Access (SMA) or S-band Single Access (SSA). The omni-antennas are configured to give S-band selected hemispherical coverage for emergency operations using TDRS-SSA service or the Deep Space Network (DSN). The HGAS and omni-antennas are connected to the C&DH module through the RF Interface Box (RFIB).

The RF Interface Box (RFIB) includes the RF switches, isolation circuits, and command signal combiners.

RF switches select the antenna to be used for RF transmission.

3.5.1 On-board Computer

The UARS On-board Computer (OBC) is a digital NASA-Standard Spacecraft Computer (NSSC-1) with redundant 64K 18-bit words of storage for programs and data. The UARS OBC is part of the MMS Communications and Data Handling module and has been used on the Solar Maximum Mission (SMM), Landsat, and other NASA programs. The UARS flight software is derived from Landsat flight software.

The OBC implements a wide range of functions for various subsystems.

- For the AD&CS, the OBC provides mission-critical precision pointing plus failure detection and correction.

- For the HGAS, the OBC provides pointing control processing for semiautonomous communications through the Space Network.

- For the SSPP, the OBC provides pointing control processing for both solar and stellar observations.

- For the solar array, the OBC provides failure detection and correction by monitoring the rotation rate and commanding the alternate solar array drive if necessary.

- For the power subsystem, the OBC provides power monitoring and power management, and controlling battery state of charge.

- For the limb viewing instruments, the OBC provides limb altitude computations.

The OBC also implements a number of functions for the observatory as a whole, in its capacity as part of the Communications and Data Handling subsystem. These include the following:

- Stored command processing for control of routine observatory operation.

- Telemetry monitoring for safeguarding critical spacecraft components.

- Time computation to maintain a standard time for inclusion with telemetry and for issuance of stored commands.

- Status buffer monitoring.

Telemetry processing.

Computer data acquisition.

Ephemeris generation.

Self-test routines.

The flight executive, originally developed for the Solar Maximum Mission (SMM), is the OBC operating system. It provides the interface between software commands and hardware actions. It also acts as the interface between hardware sensors and the software that monitors them. It enables selection of the proper operating modes for subsystems controlled by the OBC, by providing the interface to ground control.

OBC self-test software is executed continually to preclude an OBC malfunction causing erroneous observatory operation. A detected failure identified by the absence of an "I'm O.K." signal from the OBC will cause the AD&CS to automatically enter the safehold mode.

3.5.2 Commands

Commands will be transmitted to UARS through the Space Network at a rate of 1000 bps when the UARS HGAS can be used, or at 125 bps through the omni-antenna when the HGAS cannot be properly pointed. When TDRS is not available, commands can be transmitted directly from ground stations at 2000 bps. Commands to UARS will be received by either the HGAS or omni-antennas and will be fed through the RFIB to the S-band transponders. Detectors in the transponders perform PN code division demultiplexing (the first level of discriminating UARS commands from those to other spacecraft) and pass the commands to the CU for processing. Command processing includes verification of the spacecraft identification code (the second and last level of discriminating UARS commands), verification that commands are free of errors, and decoding of command type.

Command error detection is provided through the use of a polynomial error detecting code. This operates in conjunction with a signal from the transponders indicating an acceptable signal-to-noise ratio. Detection of a command error will cause rejection of the command. The observatory will then telemeter the rejection to the ground and terminate command processing until a special code is received from the ground to signal that the process should be restarted. This ground and space system logic precludes the execution of erroneous commands and the distribution of commands out of sequence.

The command decoding process recognizes three types of commands: real-time commands, OBC memory load commands, and stored commands. Each command contains 48 bits.

Real-time commands are those commands that are received from the ground and immediately distributed through an RIU to the appropriate subsystem or instrument for execution. Each command is distributed to all RIUs, using the multiplex data bus supervisory line, but each command is decoded only by the RIU that is specified as part of the command code.

OBC memory load commands are executed immediately upon receipt from the ground, but differ from other real-time commands in that distribution is made directly to the OBC through the STINT rather than the RIU. Each of these commands contain 18 bits of OBC program code, and each command allows memory to be loaded either with individual words or with blocks of words.

Stored commands are those commands that the OBC stores in sequential memory buffers in random access memory, to execute at a later time. Stored commands are loaded by sending an executive request command. This identifies the information the OBC needs to load each stored command in the proper place in the designated stored command buffer. Also included with commands to be executed are GMT time-tags that determine the precise time of execution. When executed from the OBC, stored commands are distributed to subsystems and instruments through the RIU in the identical manner and format as real-time commands.

The RIU output format for UARS commands is either a 16-bit serial digital word or a discrete transistor switch closure. The command usage and RIU designation for UARS are shown in Table 3-3.

3.5.3 Telemetry

For normal operations, the C&DH subsystem uses the high-gain antenna to communicate through TDRSS S-band Single Access (SSA). This link will be scheduled for a 10- to 15-minute contact every orbit. For real-time information, the link uses a 32-kbps science data format that contains a composite of both the science and engineering data. More important, the link supports a 512-kbps playback from the onboard tape recorder. (The recorded information uses the same science data format.)

If the SSA link is not available, the observatory can still communicate through the TDRSS Multiple Access (MA) link using 32 kbps for real-time information. The MA link does not support the 512-kbps tape recorder dump.

In emergencies, when only the omni-antennas are available, the observatory can still communicate through the TDRSS SSA link using a 1-kbps engineering data format. This 1-kbps format contains the minimum data needed for operation of the observatory.

Table 3-3. UARS Command Usage

MMS	Discrete	Serial	RIU
C&DH	50	7	1A,1B
MACS	64	6	2A,2B
MPS	45	0	3A,3B
SC&CU	27	1	4A,4B
PM-1A	57	0	5A,5B
Mission Unique			
PSU	64	3	6A,6B
SSPPE	6	2	9A,9B
AAS	8	3	7A,7B
SADDE	12	2	7A,7B
HGAS	6	2	10A,10B
Instruments			
ACRIM II	0	1	18B
CLAES	41	7	23B
HALOE	6	1	12B
HRDI	30	3	24B
ISAMS	31	3	15B
MLS	34	2	27B
PEM	20	8	29B
SOLSTICE	24	2	17B
SUSIM	26	4	20B
WINDII	11	4	30B

The C&DH subsystem can also use the omni-antenna to communicate with ground stations of the Deep Space Network (DSN). This link supports both the real-time 32-kbps data format and the 512-kbps tape recorder dump.

The 32-kbps science data format is structured with 128 8-bit words per minor frame and 32 minor frames per major frame. The 1-kbps engineering data format is structured with 128 8-bit words per minor frame and 64 minor frames per major frame.

The beginning of each engineering major frame is concurrent with the beginning of a science major frame. And the beginning of each science major frame is concurrent with the beginning of an engineering minor frame. (See Figure 3-7.)

Science Minor Frame (SMIF)	1 frame / 32 msec.
Science Major Frame (SMAF)	1 frame / 1.024 sec.
Engineering Minor Frame (EMIF)	1 frame / 1.024 sec.
Engineering Major Frame (EMAF)	1 frame / 65.536 sec.

The spacecraft data functions that will be sampled in the science minor frame are shown in Table 3-4. Table 3-5 lists the samples per EMAF that are required by the various spacecraft and instrument subsystems.

Both the science and engineering formats are produced by the CU from data that are sequentially received from the various UARS subsystems and instruments. Data acquisition makes use of the same multiplex data bus and RIUs used for command distribution. The telemetry data formats — that is, data acquisition times — are controlled by the content of Read-Only Memory (ROM) devices contained in the CU. As a backup, and for convenience during ground integration and test, the OBC can also control the telemetry formats.

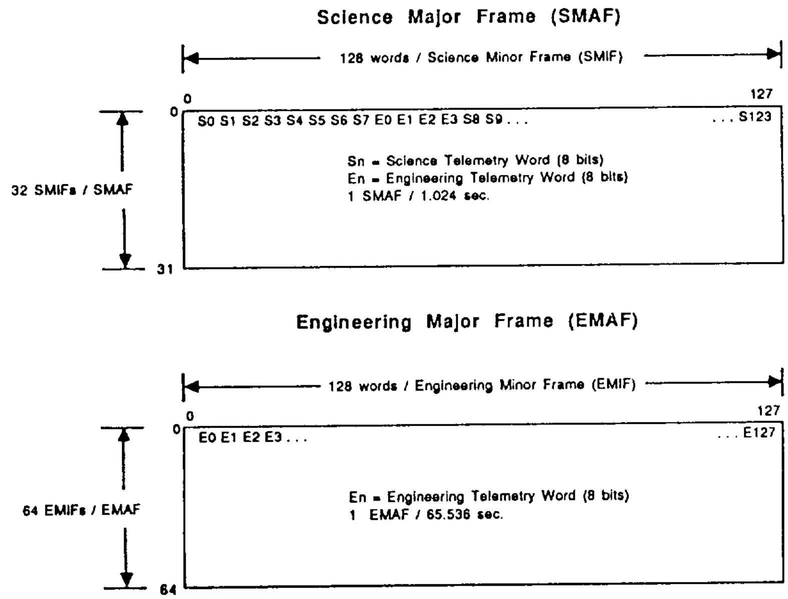


Figure 3-7. The Science Major Frame consists of 32 minor frames while the Engineering Major Frame consists of 64 minor frames. Both types of minor frames consist of 128 8-bit words. As shown above, 1 Engineering minor frame is imbedded in each Science major frame.

3.6 Thermal Control Subsystem

Functional and Design Description of Subsystem

The Thermal Control Subsystem (TCS) not only maintains acceptable equipment temperatures, but is also responsible for controlling overall structure temperatures to minimize thermal distortion and keep instrument pointing errors within prescribed limits.

Table 3-4. Science Minor Frame Format

WORD	FUNCTION	WORD	FUNCTION	WORD	FUNCTION	WORD	FUNCTION
0	SYNC 'D7'	1	SYNC '99'	2	SYNC '07'	3	CU STAT
4	SMIF CNT	5	SMIF CNT	6	S/C DATA	7	S/C DATA
8	ENG DATA	9	ENG DATA	10	ENG DATA	11	ENG DATA
12	OBC	13	OBC	14	OBC	15	OBC
16	OBC	17	OBC	18	OBC	19	S/C DATA
20	S/C DATA	21	S/C DATA	22	S/C DATA	23	S/C DATA
24	S/C DATA	25	S/C DATA	26	S/C DATA	27	S/C DATA
28	ACRIM II	29	ACRIM II	30	S/C DATA	31	S/C DATA
32	CLAES	33	CLAES	34	CLAES	35	CLAES
36	CLAES	37	CLAES	38	CLAES	39	CLAES
40	CLAES	41	CLAES	42	CLAES	43	CLAES
44	HALOE	45	HALOE	46	HALOE	47	HALOE
48	HALOE	49	HALOE	50	HALOE	51	HALOE
52	HALOE	53	HALOE	54	HALOE	55	HALOE
56	HALOE	57	HALOE	58	HALOE	59	HALOE
60	HRDI	61	HRDI	62	HRDI	63	HRDI
64	HRDI	65	HRDI	66	HRDI	67	HRDI
68	HRDI	69	HRDI	70	HRDI	71	HRDI
72	HRDI	73	HRDI	74	HRDI	75	HRDI
76	HRDI	77	HRDI	78	HRDI	79	S/C DATA
80	ISAMS	81	ISAMS	82	ISAMS	83	ISAMS
84	MLS	85	MLS	86	MLS	87	MLS
88	MLS	89	SPARE	90	SPARE	91	S/C DATA
92	PEM	93	PEM	94	PEM	95	PEM
96	PEM	97	PEM	98	PEM	99	PEM
100	PEM	101	PEM	102	PEM	103	PEM
104	PEM	105	PEM	106	SOLSTICE	107	S/C DATA
108	SUSIM	109	SUSIM	110	SUSIM	111	SUSIM
112	SUSIM	113	SUSIM	114	SUSIM	115	SUSIM
116	WINDII	117	WINDII	118	WINDII	119	WINDII
120	WINDII	121	WINDII	122	WINDII	123	WINDII
124	S/C DATA	125	S/C DATA	126	PARITY	127	PARITY

The TCS uses a passive design augmented by electrical heaters. The box-like primary structure is covered by multi-layered thermal blankets. These serve two basic purposes. First, they insulate the structure from variations of sunlight and thermal radiation. Second, by creating a thermal cavity around the structure, they permit the maintenance of nearly uniform temperatures – and low thermal distortion – throughout the structure.

The sensor portions of the UARS scientific instruments are thermally isolated from the Instrument Module support structure, and they provide their own temperature control. However, the TCS does provide thermal control for the electronic box portions of several of the instruments. In addition, the TCS provides stringent temperature control for the three instruments mounted on the Solar Stellar Pointing Platform (SSPP).

Table 3-5. Engineering Format - Samples/Engineering Major Frame

Subsystem	Samples
C&DH	1006
NBTR	528
MACS	1430
ESAM	436
PM-1A	185
SC&CU	137
MPS	466
PSU	416
SADDE	68
SSPP	132
HGAS	60
Thermal	82
Instruments	
ACRIM II	76
CLAES	448
HALOE	234
HRDI	284
ISAMS	80
MLS	482
PEM	358
SOLSTICE	73
SUSIM	93
WINDII	103
TOTAL	7177

The TCS also accommodates conduction and radiation interfaces with the STS orbiter in the launch phase.

The thermal control techniques for the Instrument Module and thermally-significant mission-unique hardware are shown in Table 3-6.

Table 3-6. Thermal Control Techniques

ITEM	CONTROL TECHNIQUES	TCS IMPLEMENTATION
IM Truss	Passive	Blankets Heaters (backup only) Black paint
Equipment Panels	Passive with heaters	Silver/teflon coating Blankets Heaters Electronic thermostats Black paint
SSPP	Passive with heaters	Silver/teflon coating Blankets Heaters Electronic thermostat
Solar Array	Passive	White paint (backside)
HGA Reflector	Passive	White paint (both sides)
Instrument Mounts	Passive titanium (Ti) isolation	Blankets

3.7 Solar Stellar Pointing Platform

Functional Description of Subystem

The Solar Stellar Pointing Platform (SSPP) is a two-axis gimballed platform that points three instruments (SUSIM, SOL-

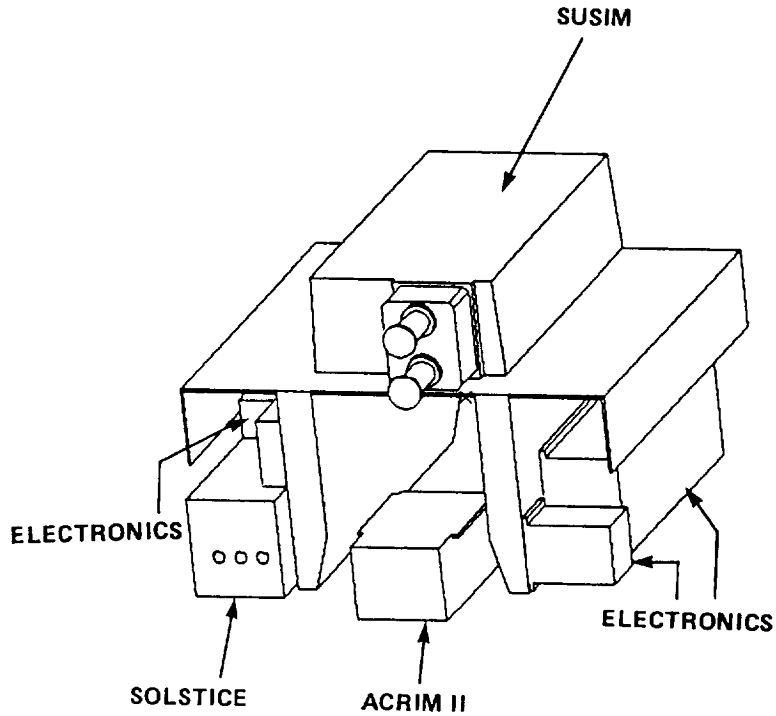


Figure 3-8. The Solar Stellar Pointing Platform Configuration

STICE, and ACRIM II). (See Figure 3-8.) For solar observations, it provides instrument pointing at the sun during portions of each orbit. In addition, it points SOLSTICE toward selected bright stars for calibration. Figure 3-9 shows an SSPP block diagram.

Functional and Design Description of Individual Components

In addition to the actual aluminum platform which houses the three instruments and redundant platform sun sensors, the SSPP subsystem includes a two-axis gimbal assembly with redundant drive motors and shaft encoders, a control electronics box, and associated control software in the OBC. The SSPP also includes redundant drive mechanisms and hardware to retain the

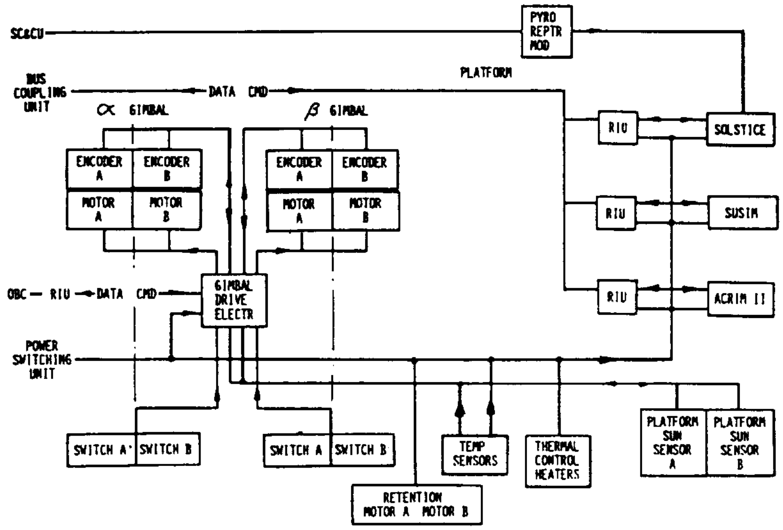


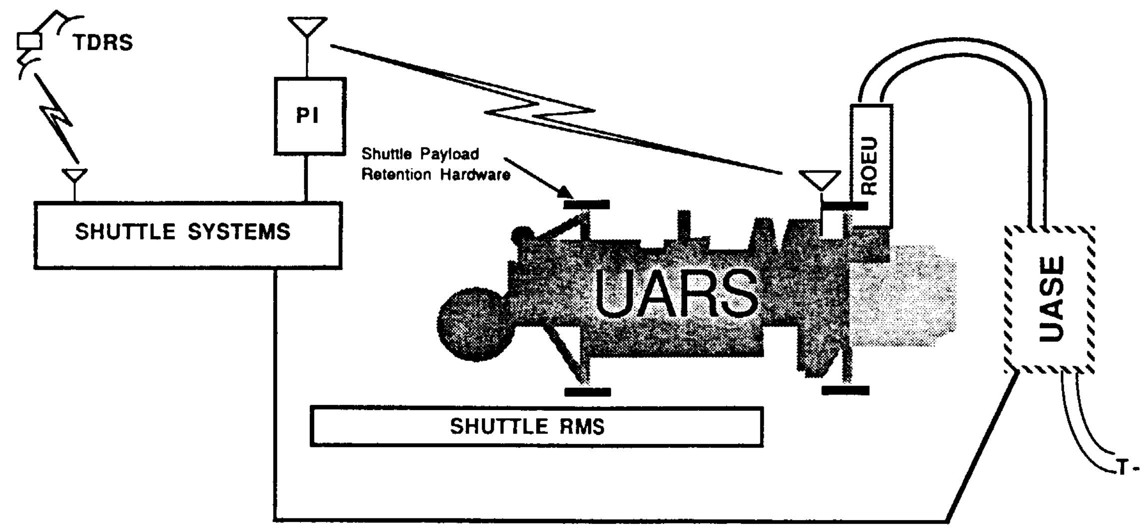
Figure 3-9. Block Diagram for the Solar Stellar Pointing Platform

platform during launch, release it for orbital operation, and relatch it for STS retrieval. The OBC can use data from the platform sun sensor for closed-loop sun tracking. For star tracking, it will be limited to using data derived from inertial attitude knowledge and platform gimbal position encoders. The OBC can also point the platform toward the sun using on-board ephemerides and attitude knowledge.

3.8 Shuttle Interfaces

Functional and Design Description of Interface Hardware

The interfaces between the UARS payload and the orbiter are shown in the block diagram in Figure 3-10. The interfaces are grouped into six hardware-oriented areas:



PI - Payload Interrogator
UASE - UARS Airborne Support Equipment
RMS - Remote Manipulator System
ROEU - Remotely Operated Electrical Umbilical
T-0 - Time Zero Umbilical
TDRS - Tracking and Data Relay Satellite

Figure 3-10. This figure shows the UARS interfaces with the Shuttle.

The UARS Airborne Support Equipment (UASE) consists of the electrical link between UARS and STS, the mechanical hardware needed to support the link, and the STS ground support equipment. The UASE provides control for power-up and power-down of the spacecraft. It also provides command and telemetry links and critical signal monitoring while UARS is in the orbiter cargo bay. The UASE remains in the payload bay after UARS deployment.

The Remotely-Operated Electrical Umbilical (ROEU) provides the only electrical interface connection between UARS and the orbiter via the UASE. This connection will be separated remotely via an STS panel prior to unlatching of the payload retention latches. The ROEU connection is designed for repeated matings and dematings.

The payload retention hardware provides the primary mechanical interface between the observatory to the STS through six outrigger trusses. Four of the trusses provide pins which attach to the standard trunnion fittings mounted on the STS payload bay sills. The remaining two trusses provide keel pins which attach to the standard keel fittings mounted on the STS payload bay keel. Additionally, scuff plates at the trunnion pins guard against inadvertent contact during installation, deployment, or retrieval.

The Remote Manipulator System (RMS) will be used for deployment of the UARS observatory after the STS has achieved parking orbit and UARS check-out is completed. The RMS will attach to the UARS observatory using the end effector on the RMS and an STS-provided grapple fixture mounted on the UARS.

The T-0 umbilical consists of hardware connections between the payload and its ground support equipment. The umbilical connects to the orbiter, which provides connections to the UASE, and through the UASE to UARS. The umbilical provides pre-launch control and monitoring of selected UARS functions until just prior to launch, and separates from the STS at launch. It also provides post-landing abort CLAES monitoring and cryostat heater control in the event of a shuttle abort.

The STS Payload Interrogator (PI) provides an RF link to establish telemetry and command capability via the orbiter. It can also provide a limited amount of contingency support for problems involving the hard-line interfaces between the STS and UARS, or the direct line between TDRS and UARS.

SECTION 4
THE UARS INSTRUMENTS

Section **Page**

4. The UARS Instruments

This section briefly describes the ten observatory instruments, looking at the purpose, function, and operation of each. The descriptions also include background information, measurements, summary tables, functional block diagrams, and sketches as appropriate.

4.1 Solar Ultraviolet Spectral Irradiance Monitor

Purpose

The observations of the Solar Ultraviolet Spectral Irradiance Monitor (SUSIM) instrument have a threefold general objective: 1) to improve the accuracy of knowledge of the absolute solar fluxes, 2) to provide highly accurate traceability of solar fluxes to a variety of ultraviolet radiation standards to be able to establish long-term (solar cycle) variations, and 3) to measure the variability of solar fluxes during several different time periods ranging from flare-produced changes (hours) to the variability caused by solar rotation (27 days).

More specifically, an accurate knowledge of the sun's output and its variability in the 120 to 400 nm wavelength range is necessary to test models of the high atmosphere. The main objective is to establish values for solar ultraviolet fluxes and their changes over a solar activity cycle in these wavelengths. Of particular interest is the variability of the solar continuum in the 170 to 210 nm region, which is absorbed in the Schumann-Runge bands of the Earth's atmosphere.

Functional Description

Ultraviolet intensity measurements are particularly difficult because the very solar radiation which is to be measured with high precision is also the main cause of instrument degradation.

Therefore, in order to achieve the goals for SUSIM, a new approach will be used, with the main emphasis on improvements in four different areas: 1) improvements of existing calibration methods, 2) a new scheme of strict environmental control of the instrument, 3) elaborate combination of in-flight calibration and redundant measuring methods to distinguish instrument changes from true solar flux variations, and 4) cross-calibration of the long-duration SUSIM on UARS by its sister instrument flown for short periods on Space Shuttle missions.

Instrument Description

SUSIM consists of two identical double-dispersion scanning spectrometers, seven detectors, a structural and environmental control case, associated electronics, and a set of ultraviolet calibration light sources. The general layout of the SUSIM instrument is shown in Figure 4-1. The functional makeup of the instrument, and its interface with the UARS, is shown in the functional block diagram Figure 4-2.

Each of the two spectrometers has interchangeable entrance and exit slits that provide a spectral resolution of 0.15 nm, 1.0 nm, or 5.0 nm over the entire spectral range. For each spectrometer, wavelength scanning is achieved by synchronously moving the two gratings, while keeping the entrance and exit slits fixed. As the spectrum is scanned, the first grating is pivoted off-center to compensate for the changing focal distance. One spectrometer will be used almost continuously during the daylight portion of each solar-pointed orbit. The second will be used infrequently, and only to track changes in the sensitivity of the first.

During operation the SUSIM will monitor eight broad-band channels (5.0 nm resolution) and eight narrow-band channels (0.15 nm resolution). Broad-band measurements will be made by five MgF_2-windowed photodiodes – three with RbTe cathodes and two with bialkali cathodes. Narrow-band measurements will be made with two MgF_2-windowed photon counters – one with

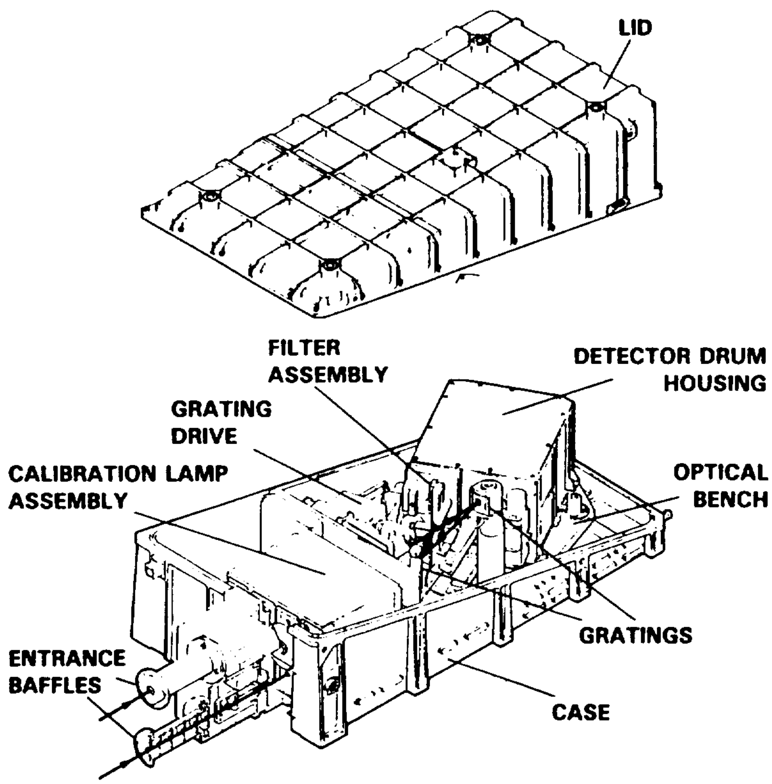


Figure 4-1. SUSIM Configuration

an RbTe photocathode for shorter wavelengths and one with bi-alkali photocathode for longer wavelengths. The 1.0 nm middle-band mode will use a combination of detectors. All seven detectors are mounted inside a rotation cylinder within SUSIM, and each can be rotated into observing position at either of the two spectrometers.

Because solar irradiance increases by five orders of magnitude between 130 and 400 nm, a double-dispersion design is essential for thorough stray-light rejection. The only region where contamination from second-order short-wavelength light can be expected is at 243.2 nm, and then only if scanned with the RbTe cathode. A second-order deuterium lamp suppression filter mechanism is behind the exit slit wheel. A filter wheel containing three neutral density filters is also in the optical path following the exit slits. These can reduce count rates to within detector operating range, if necessary.

The SUSIM electronics receive uplink commands and act upon them; they control various drive mechanisms, including those for detector wheel rotation, opening and closing of the aperture door, opening and closing of the window shutter, filter selection, grating movement, and slit selection. They also gather both science data (in the form of counts per programmable period for 14 different optics and sensor arrangements) and housekeeping data. They then format the data and send it to the satellite Command and Data Handling Subsystem with data headers and frame sync codes. Table 4-1 summarizes the SUSIM instrument parameters. The electronic system has been made 100% redundant to assure operation for the UARS mission.

The SUSIM electronics include a microprocessor-based instrument controller for automatic instrument control. This is designed for flexibility, and allows for changes to be made in control parameters if necessary. The interface electronics are contained in separate plug-in boards. Preprogrammed sequencing for slit selection, grating positioning, detector selection, and so forth, will be in place at launch. However, the instrument design also provides the ability to change sequencing in flight by command from the ground.

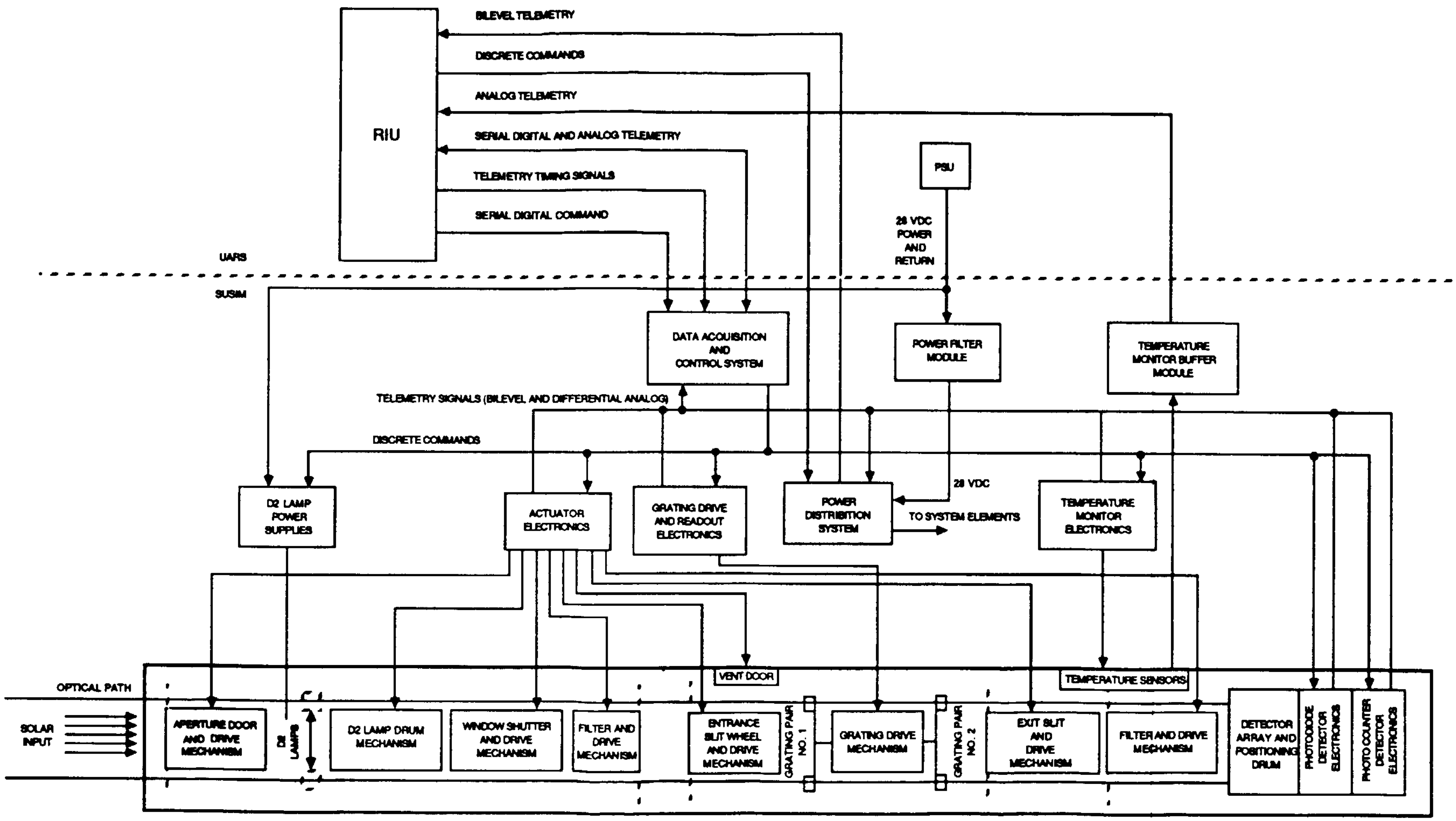


Figure 4-2. SUSIM Functional Block Diagram

Table 4-1. SUSIM Instrument Parameters

Type of measurement:	Full disk solar spectral irradiance.
Type of instrument:	Double-dispersion scanning spectrometer.
Geophysical Parameters Determined:	Solar electromagnetic energy incident on atmosphere.
Wavelength coverage:	120 to 400 nm.
Comments:	Onboard calibration to determine long-term sensitivity.
Spectral resolution:	0.15, 1.0, and 5.0 nm.
Instrument weight:	237 lb.
Average power:	21 watts.
Data rate:	2 kbps.

4.2 Solar Stellar Irradiance Comparison Experiment

Purpose

The Solar Stellar Irradiance Comparison Experiment (SOLSTICE) has a similar objective to SUSIM, but takes a different approach to calibrating the instrument, using a set of bright ultra-violet stars for reference calibration.

The objective of the SOLSTICE is to determine solar variability on three basic time scales:

1. short-term variations spanning time periods of minutes to hours (exemplified by solar flares),

2. intermediate-term variations lasting days to weeks (characterized by the solar rotation and the development of active regions),

3. long-term variations (associated with the 11-year sunspot cycle or the 22-year magnetic field cycle).

The instrument will have a high relative accuracy and precision and will follow the short and intermediate-term solar variations at and below the one-percent level.

It will be difficult to infer long-term solar variability directly from the SOLSTICE measurements because of the limited lifetime of UARS relative to the solar cycle. However, the unique feature of the SOLSTICE is its ability to compare accurately (to within 1%) the solar irradiance with the ultraviolet flux of bright blue stars. These stars then become the standards against which the solar irradiance is measured. Other instruments can remeasure these solar/stellar ratios at all future times. The direct comparison of the future ratios to those obtained by UARS can then be used to infer accurately the long-term variability of our sun.

Functional Description

The SOLSTICE will measure the magnitude of solar spectral irradiance of the total solar disk in the wavelength range 115 to 430 nm. During the daylight portion of each orbit, the pointing platform will point the instrument to sun center and the SOLSTICE will perform full wavelength scans. During the nighttime portion of most orbits, the SOLSTICE will be reconfigured to use the stellar entrance and exit slits, and the platform will be pointed to one of the selected calibration stars. The instrument will be in a fixed-wavelength mode and accumulate stellar data for approximately 15 minutes.

To compare accurately the irradiance of the sun to that of a star, SOLSTICE uses the same optical system for both solar and stellar observations: the same mirrors, the same gratings, and the same detectors. The SOLSTICE accommodates the seven to eight orders of magnitude difference between the solar and stellar flux by varying measurement time, spectral bandpass, and the instrument aperture.

Instrument Description

The SOLSTICE, as shown in Figure 4-3, consists of a single instrument mounted to the Solar Stellar Pointing Platform (SSPP). The spectrometer includes three separate spectral channels, each with a separate grating and photomultiplier tube detector, to cover the full spectral range 115 to 430 nm. These three channels are stacked so that they share a common wavelength drive and common entrance and exit slit interchange mechanism.

The SSPP platform sun sensor is aligned to the SOLSTICE optic axis and is used to control the attitude of the SSPP for solar pointing. Stellar pointing is open loop using the onboard computer with attitude reference from the spacecraft attitude control subsystem and platform position encoders.

The optical design is shown in Figure 4-4 (not to scale). In both solar and stellar configurations, the optical flat is used only to fold the incoming beam. In the solar configuration, the f/100 solar beam is incident through a small entrance aperture (slit), diffracted by the grating, and focused on a small exit slit by the off-axis elliptical mirror. In the stellar configuration, the collimated stellar beam is incident through a large aperture, diffracted by the grating, and focused at a large exit slit at the off-axis ellipse focus. The optical layout is designed to maintain a similar illumination between solar and stellar configurations.

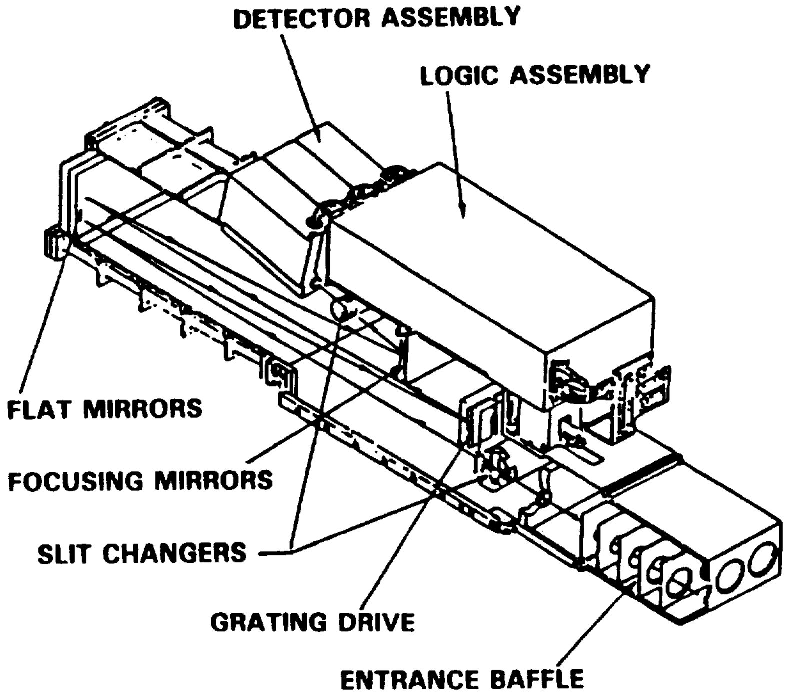
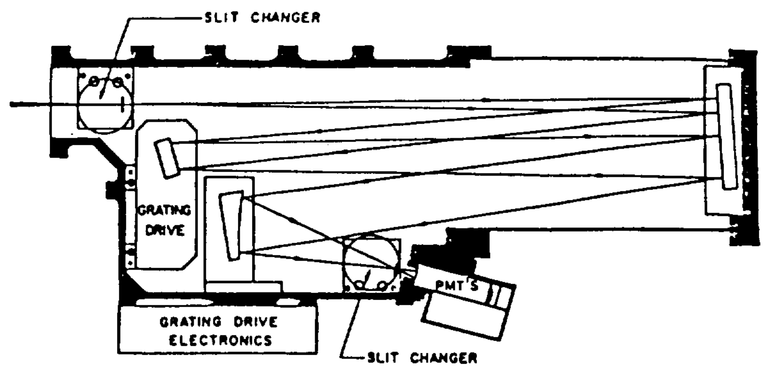
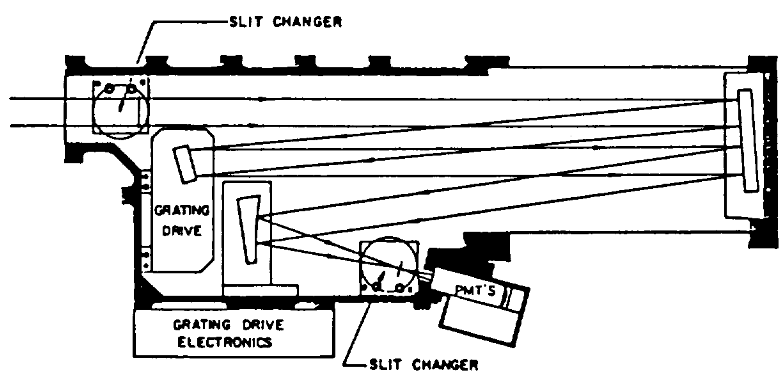


Figure 4-3. SOLSTICE Configuration

SOLSTICE uses three photomultiplier tubes. Each tube is capactively coupled to its individual Pulse Amplifier Discriminator (PAD) unit. The shaped output pulses are available to the counting electronics. The phototubes are of the EMR 510 series. The first is a G-type (cesium iodide photocathode) with a magnesium fluoride window; the second is F-type (cesium telluride photocathode) with a fused-silica window; and the third is an N-type (high temperature bi-alkali photocathode) with a glass window. The G-type is sensitive from 115 nm to 200 nm, the F-type from 165 nm and 330 nm, and the N-type from 300 nm to 650 nm.



SOLAR



STELLAR

Figure 4-4. SOLSTICE Optical Design Summary

The SOLSTICE electronics consists of the three phototubes and pulse counting systems plus the grating control system, command-telemetry interface and synchronization, and motor interface and control. There is also a microprocessor in a bus architecture for executive control and decision making. The microprocessor will control the mode formatting and sequencing of the instrument based on commands presented to it. The data system consists of the photomultiplier tubes and 16-bit pure binary counters. The data are multiplexed into the telemetry stream along with instrument status and bit sync. The grating control logic is a closed-loop motor control system capable of articulating the grating from microprocessor control inputs. The microprocessor has executive control for mode execution of grating control, integration, and data start logic, and has access to the data channels for storage or manipulation.

A functional block diagram is shown in Figure 4-5. Table 4-2 summarizes the SOLSTICE instrument parameters.

Table 4-2. SOLSTICE Instrument Parameters

Type of measurement:	Full disk solar spectral irradiance.
Type of instrument:	Three-channel grating spectrometer.
Geophysical Parameters Determined:	Solar electromagnetic energy incident on atmosphere.
Wavelength coverage:	115 to 440 nm.
Comments:	Uses comparison with set of UV stars for determination of long-term stability.
Spectral resolution:	Solar: 0.12 and 0.25 nm. Stellar: 5.0 and 10 nm.
Instrument weight:	41 lb.
Average power:	8 watts.
Data rate:	0.250 kbps.

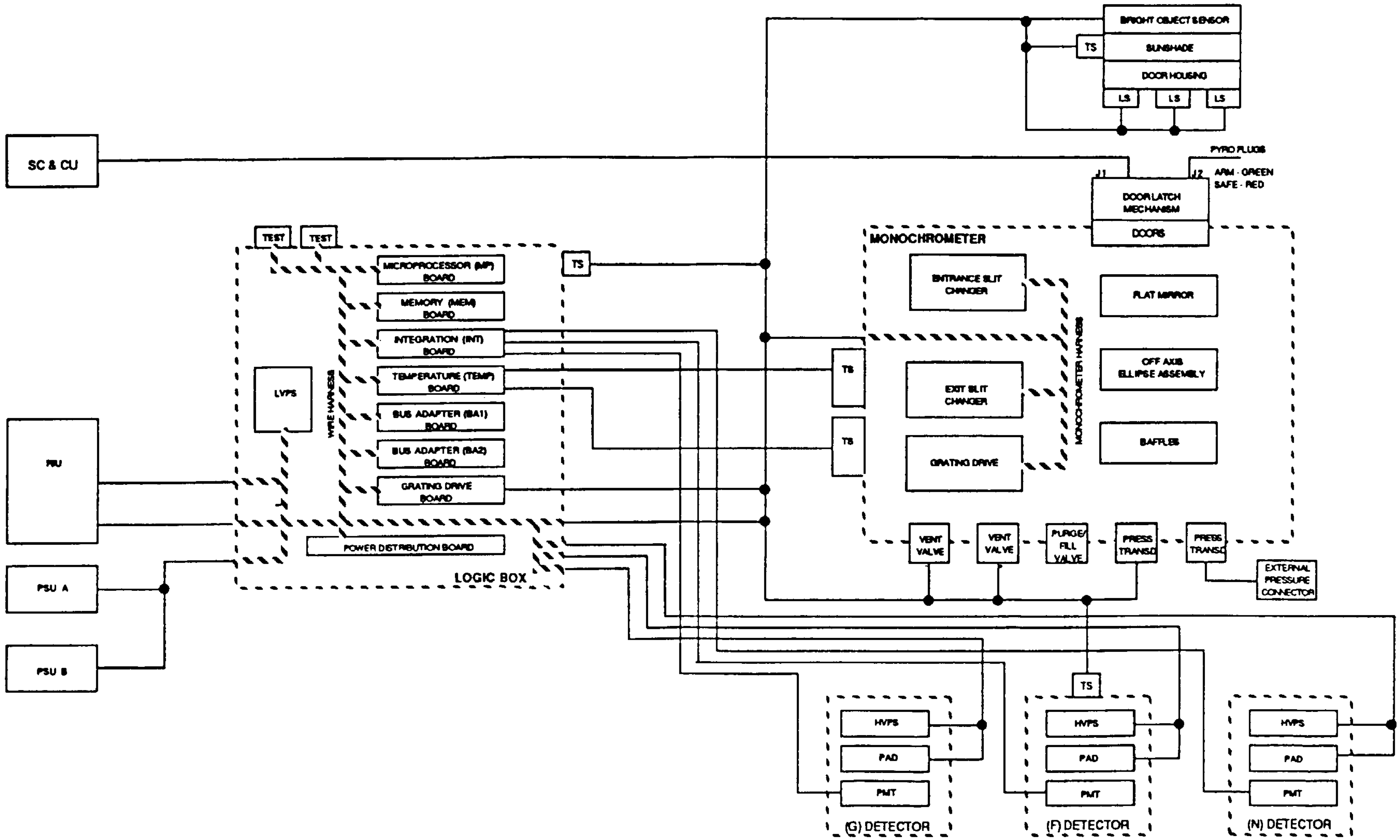


Figure 4-5. SOLSTICE Functional Block Diagram

4.3 Particle Environment Monitor

Purpose

The purpose of the Particle Environment Monitor (PEM) is to determine both the global input of charged-particle energy into the Earth's stratosphere, mesosphere, and thermosphere and the predicted atmospheric responses. The PEM provides an integrated instrumentation approach that details both local and global energy inputs.

The PEM will provide information for pursuing six specific objectives. These are:

- to determine the effects of energetic particles on stratospheric, mesospheric, and thermospheric chemistry,
- to determine ozone reduction induced by solar protons,
- to identify sources of nitric oxide,
- to determine the effects of energetic particles on noctilucent cloud formation,
- to study the physics of the interaction of particle fluxes with the atmosphere,
- to investigate anomalous ionization produced by energetic electrons.

Functional Description

The PEM consists of four primary instrument subunits: the Medium-Energy Particle Spectrometer (MEPS), the High-Energy Particle Spectrometer (HEPS), the Atmosphere X-Ray Imaging Spectrometer (AXIS), and the Triaxial Magnetometer (MAG).

MEPS and HEPS will measure particle fluxes in the energy range within which significant influences on the atmosphere can occur. However these particle measurements are taken at one point in space. AXIS offers a complementary approach. Its measurements yield wide spatial coverage of particle energy by measuring the X-rays emitted and scattered upward from the slowing down of energetic electrons in the atmosphere.

More specifically, the MEPS and HEPS will provide direct in-situ measurements of precipitating electrons in the energy range from 1 eV to 5 MeV (for MEPS) and protons in the energy range of 1 eV to 150 MeV (for HEPS). AXIS will provide global images and energy spectra of atmospheric X-rays produced by electron precipitation over the energy range 2 to 300 keV. MAG will provide a measure of the joule energy disposition.

Instrument Description

Both MEPS and HEPS will be measuring weak mid-latitude precipitating fluxes in the presence of significant background radiation from trapped particles, thus requiring discrimination against such fluxes. MEPS will accomplish this discrimination by passive low Z/high Z shielding. HEPS will use an active, anticoincidence scintillator in addition to passive shielding.

Multiple sampling angles over the upper and lower hemisphere of the spacecraft will be required to evaluate precipitating fluxes. MEPS will use eight electrostatic analyzers in an angular array covering the region between the zenith and the nadir. The MEPS analyzers will share common electronics. HEPS will use eight telescopes oriented on the spacecraft such that the required angular coverage is achieved over the range of magnetic field declination and inclination encounterd by UARS.

The MEPS and HEPS subunits plus the electronics mounted on the zenith boom are collectively referred to as the Zenith Energetic Particle System (ZEPS); the subunits mounted on the nadir platform are referred to as the Nadir Energetic Particle System (NEPS).

The ZEPS boom carries a Medium-Energy Particle Spectrometer (ZMEPS), two High-Energy Particle Spectrometers (HEPS1 and HEPS2), a Remote Power Unit (RPU), and the MAG. ZMEPS includes five electrostatic analyzer detectors, two high-voltage units, and portions of the zenith interface electronics. HEPS1 and HEPS2 are identical except for viewing angles. Each consists of two telescope-type silicon solid-state charged-particle detectors and one low-energy proton spectrometer. The MAG is mounted on a one-meter boom extending horizontally from the ZEPS boom. An analog-to-digital converter will digitize the magnetic field observations. The RPU provides the on/off control of HEPS1, HEPS2, and the two ZMEPS high-voltage units.

The NEPS platform, mounted on the Earth side of UARS, carries the NMEPS, a HEPS, and a remote power unit. The NMEPS includes three electrostatic analyzer detectors, one high-voltage unit, and portions of the nadir interface electronics. The HEPS consists of two telescope-type silicon solid-state charged-particle detectors. The remote power unit electronics provides control of HEPS and the NMEPS high-voltage unit, and provides low-voltage monitoring of NEPS.

AXIS consists of two identical units each containing eight telescopes. The telescopes are made of thin silicon and thicker germanium solid-state sensors. Pulse-height analysis of the output pulses from each of the sensor systems will provide the X-ray spectra. Active anticoincidence scintillators and passive aluminum and tungsten shielding will be used to discriminate against background radiation. Thermal radiators will provide passive cooling to lower noise and hence achieve low-energy photon measurements.

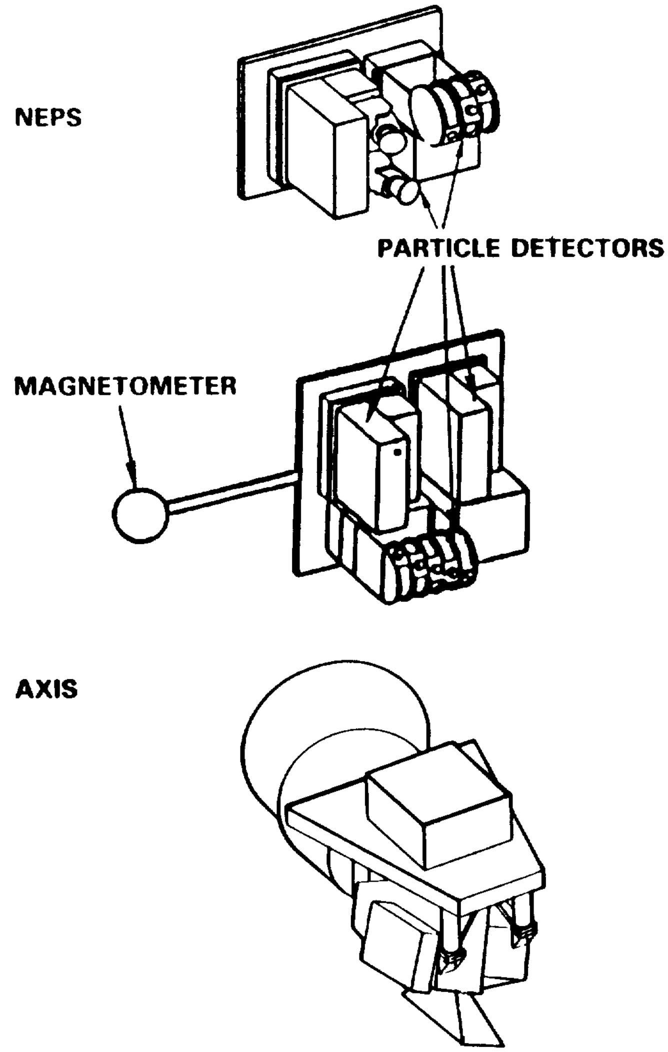


Figure 4-6. PEM Configuration

The PEM configuration is shown in Figure 4-6. A functional block diagram is shown in Figure 4-7. Table 4-3 summarizes the PEM instrument parameters

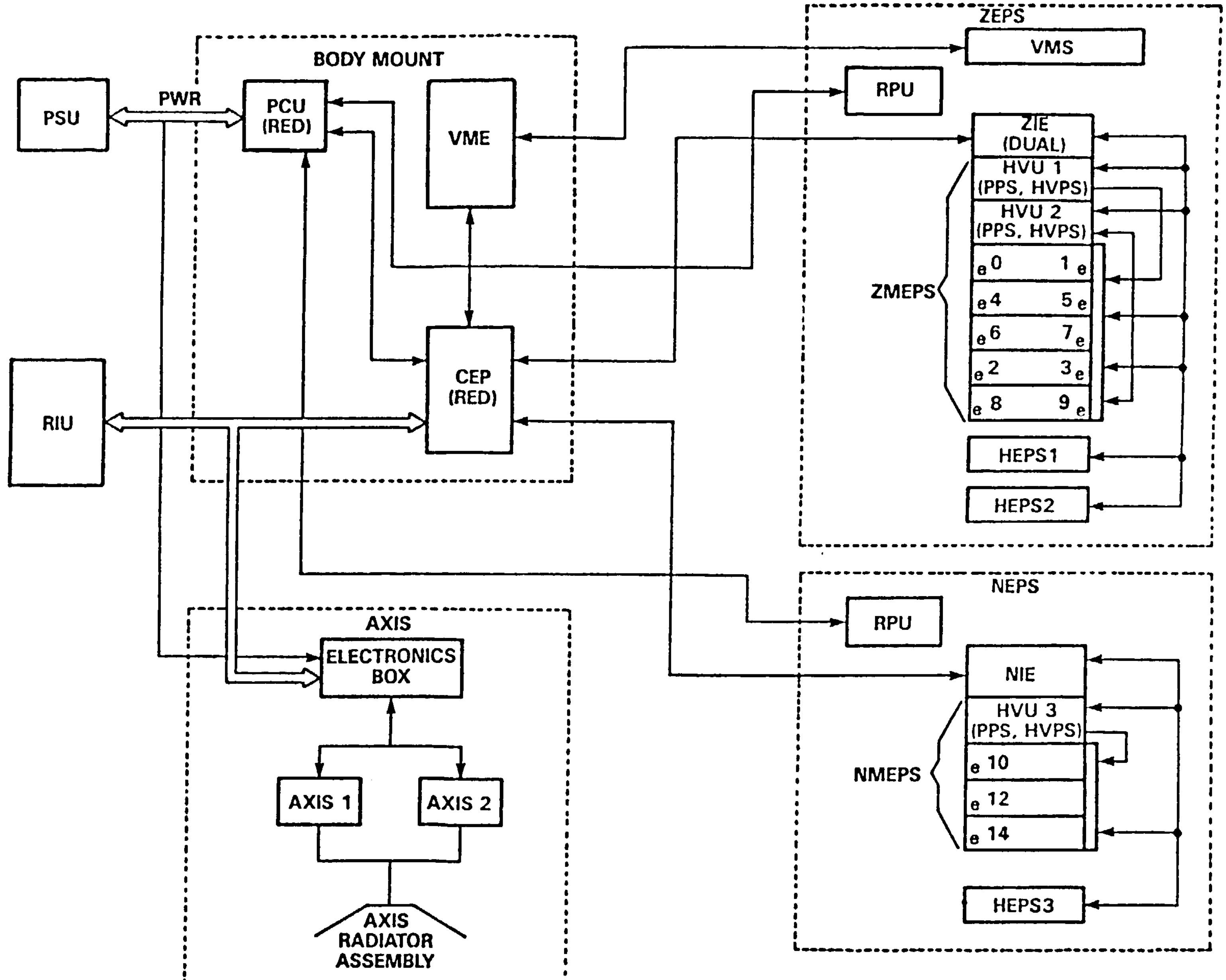


Figure 4-7. PEM Functional Block Diagram

Table 4-3. PEM Instrument Parameters

Type of measurement:	Magnetospheric energy input to atmosphere.
Type of instrument:	Electrostatic analyzers, solid-state range energy telescopes, X-ray imaging spectrometer, and vector magnetometer.
Geophysical Parameters Determined:	Electron: 1 eV to 5 MeV. Protons 1 eV to 150 MeV. X-rays: 2 keV to 300 keV. Magnetic field: 24 to 60,000 nT.
Instrument weight:	199 lb.
Average power:	80 watts.
Data rate:	3.5 kbps.

4.4 Cryogenic Limb Array Etalon Spectrometer

Purpose

The primary objective of the Cryogenic Limb Array Etalon Spectrometer (CLAES) instrument is to obtain global measurements of the concentrations of a series of stratospheric minor species which are of significant interest to the photochemistry of the stratosphere, in general, and the ozone layer, in particular.

The species of interest include N_2O, NO, NO_2, and HNO_3 in the nitrogen family, and $CFCl_3$ (FC-11), CF_2Cl_2 (FC-12), HCl, ClO, and $ClONO_2$ in the chlorine family, in addition to O_3, H_2O, CH_4, and CO_2. This measurement set includes some of the more important source, radical, and reservoir species involved in the ozone layer chemical system.

Functional Description

CLAES directly measures atmospheric radiance, and then infers neutral composition. The radiance field is important to energy input and loss studies, radiation budgets, and climatic modeling. Scientific data will consist of vertical profiles of the concentrations of the above species and temperature over the altitude range of 10 to 60 km, acquired with vertical resolution of 2.8 km, and at 65 sec intervals.

Instrument Description

The CLAES instrument involves the remote measurement of Earth limb emission spectra. Characteristic infrared vibration rotation line spectra of the species of interest are measured simultaneously at 20 different limb altitudes from 10 to 60 km. The measured spectral radiances are then inverted through an iterative relaxation process to yield concentration and temperature at each of the altitude points or pressure heights.

The 50 km altitude coverage and 2.8 km footprint size are obtained through the use of a linear array of 20 discrete detectors. Pointing and orientation of the array with respect to the limb vertical coordinate are provided by the UARS attitude control system. CLAES is capable of internal adjustment of the vertical pointing by as much as 60 km in limb altitude. The image of the array is swept horizontally across the limb as the spacecraft orbits, to provide the geographical coverage.

This limb viewing emission experiment requires high spectral resolution and high radiometric sensitivity to isolate accurately and measure weak emissions from trace species against intense backgrounds from abundant emitters. The telescope and optical system are capable of a high degree of out-of-field rejection to ensure that the very intense hard Earth surface emissions do not contaminate the lowest altitude detectors, which sample only a few tenths of a degree above the surface horizon. The optical system and detectors are cooled by cryogens to suppress thermal emission from instrument surfaces and to permit low-noise detector operation at infrared wavelengths.

Redundant microprocessors provide on-board instrument control with the facility for updating or reloading all control parameters and operational modes from the ground.

The major elements of the instrument are shown in Figure 4-8. The instrument consists of a 0.25 cm^{-1} bandwidth solid-etalon Fabry-Perot spectrometer, coupled with a reflective telescope and a solid-state linear detector array. A NE/CO_2 cryostat cools the detectors to 15.5 degrees Kelvin, the spectrometer to 50 degrees Kelvin, and telescope optics to 150 degrees Kelvin. The deployable aperture door is used to maintain system vacuum during ground hold and launch, and is used on a nominal 3-day open and 3-day closed schedule to conserve cryogen during mission lifetime. The door also serves as a secondary calibration source.

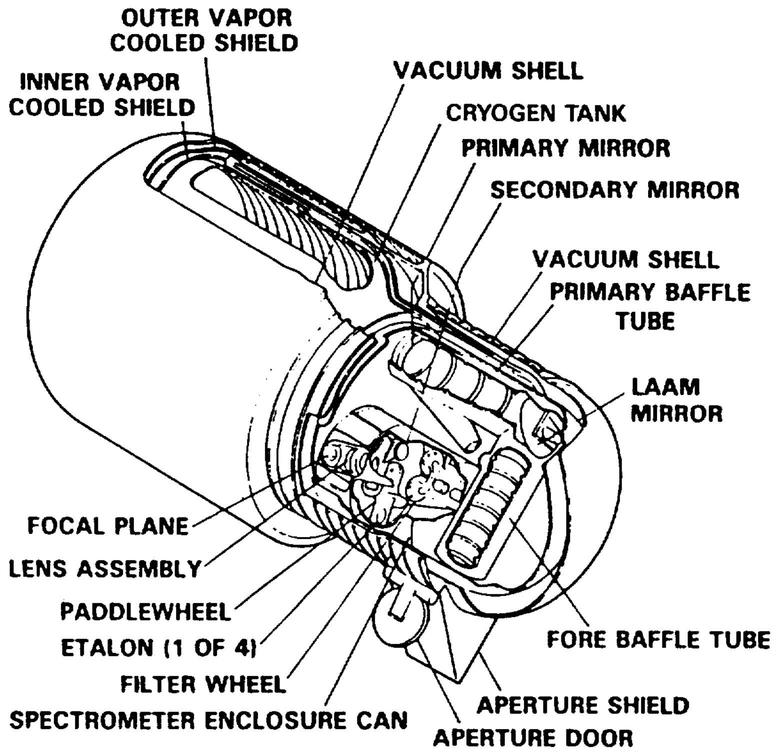


Figure 4-8. CLAES Configuration

A functional block diagram is shown in Figure 4-9. Table 4-4 summarizes the CLAES instrument parameters.

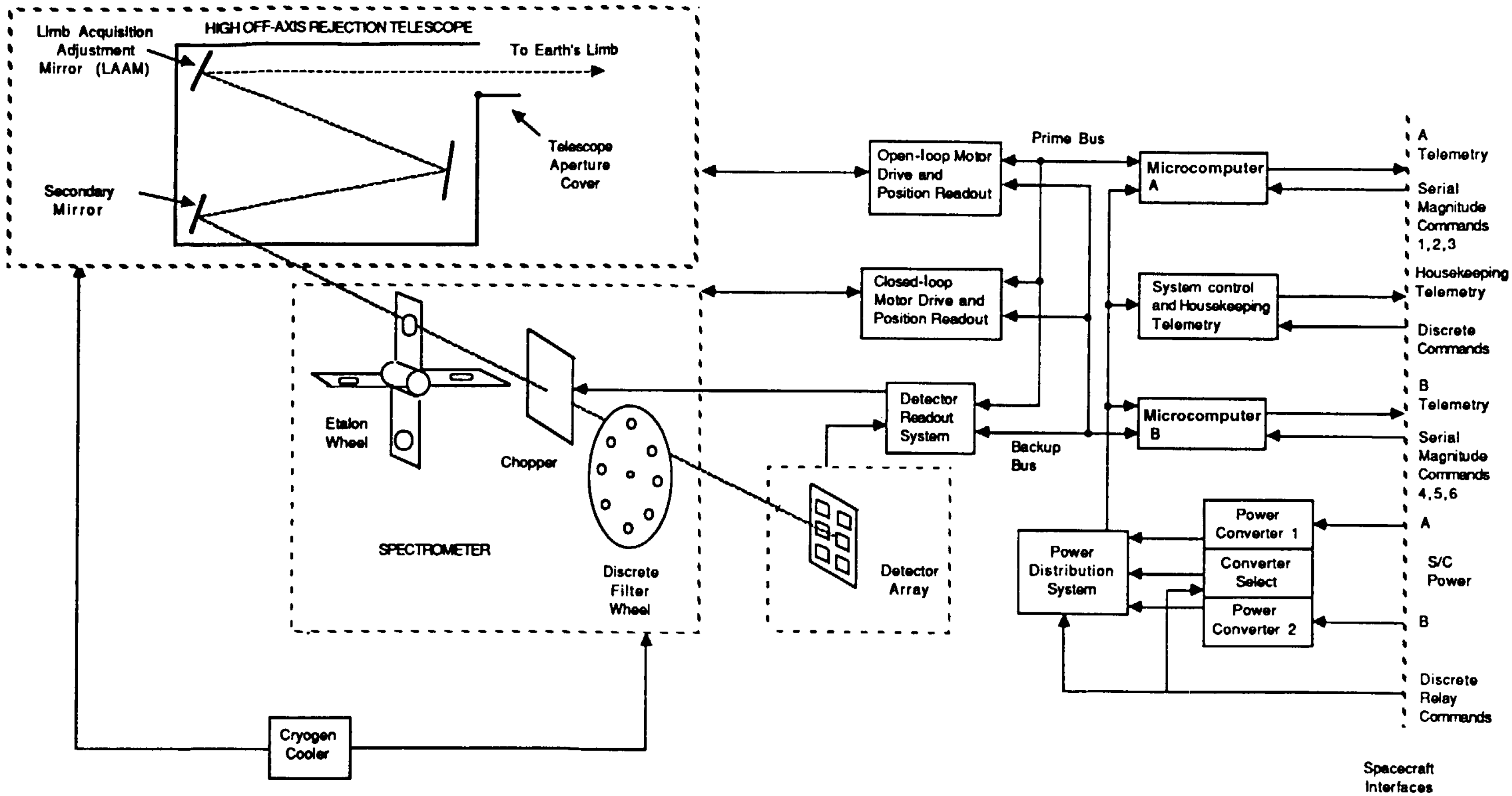


Figure 4-9. CLAES Functional Block Diagram

Table 4-4. CLAES Instrument Parameters

Type of measurement:	Infrared thermal atmospheric emission.
Type of instrument:	Tilting-etalon spectrometer with linear array detector.
Geophysical Parameters Determined:	Atmospheric temperature, N_2O, NO, NO_2, HNO_3, CF_2, CF_2 CL_2, $CFCl_3$, HCl, O_3, $ClONO_2$, CO_2, H_2O, ClO, and CH_4.
Wavelength Coverage:	3.5 to 12.7 micron.
Viewing geometry:	Atmospheric limb, 90 degrees to spacecraft velocity vector, 80 degrees maximum latitude sampled.
Comments:	Detector and optics cooled by cryogen; 15 months lifetime with 50% duty cycle.
Spectral resolution:	0.25 cm^{-1} and 0.32 cm^{-1}
Vertical field of view:	50.7 km (20 elements of 2.8 km each).
Horizontal resolution:	8.4 km instantaneous footprint.
Instrument weight:	2662 lb.
Average power:	27 watts.
Data rate:	3 kbps.
Time required to perform measurement: 65 sec nominal. Distance along spacecraft track: 495 km nominal.	

4.5 Improved Stratospheric and Mesospheric Sounder

Purpose

The scientific objectives of the Improved Stratospheric and Mesospheric Sounder (ISAMS) are to determine the thermal structure of the atmosphere and its fluctuations in space and time (e.g., with season), to investigate the photochemistry of nitrogen-containing species in the stratosphere, and to study the water vapor budget of the upper atmosphere. These objectives will be addressed by measurements of carbon dioxide (CO_2) (in four bands, for temperature determination), nitrous oxide (N_2O), nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen pentoxide (N_2O_5), nitric acid (HNO_3), ozone (O_3), water vapor (H_2O), methane (CH_4), and carbon monoxide (CO).

Functional Description

ISAMS uses infrared pressure-modulator radiometry to measure thermal emission from selected atmospheric constituents at the Earth's limb. The radiance profiles obtained in this way are used to obtain nearly global coverage of the vertical distributions of temperature and composition from 80 degrees South to 80 degrees North latitude.

Instrument Description

The ISAMS instrument shown in Figure 4-10 is derived from the Stratospheric and Mesospheric Sounder (SAMS) instrument that was flown successfully on Nimbus 7 from 1978 to 1983. Both instruments use pressure-modulator radiometry, a technique in which samples of the gas under investigation are used to make spectral filters by modulating their pressure and hence absorption characteristics in their absorption-emission lines. This gives

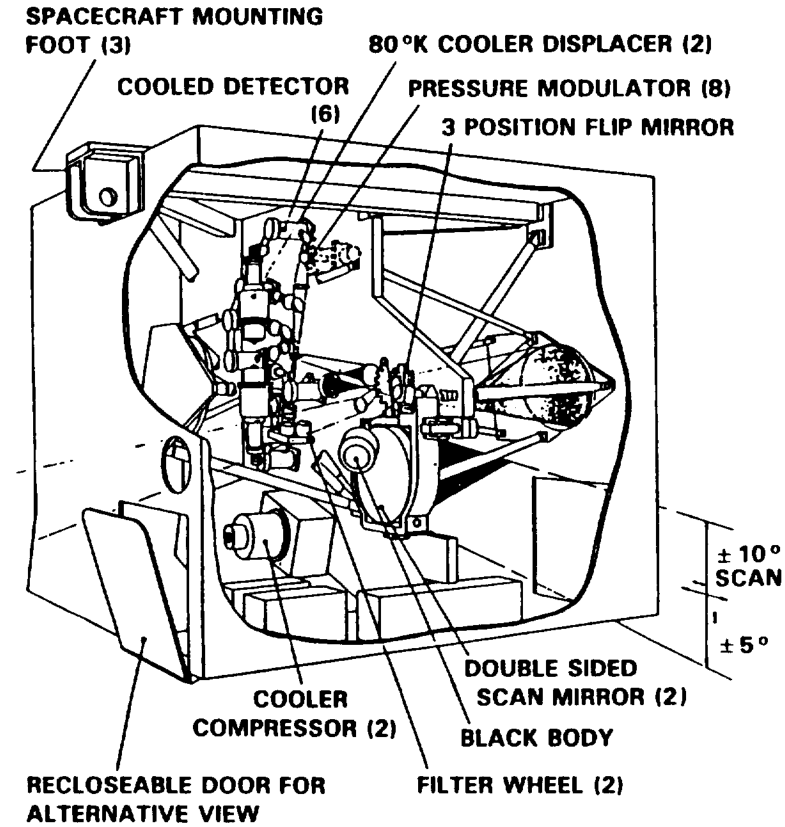


Figure 4-10. ISAMS Configuration

very highly effective spectral resolution combined with relatively efficient energy throughput. ISAMS further enhances the signal-to-noise ratio through the use of a new design of closed-cycle Stirling refrigerators to reduce the temperature of the mercury-cadmium-telluride detectors to 80 degrees Kelvin, approximately the temperature of liquid nitrogen.

The primary optics configuration consists of an off-axis (non-obscuring) reflecting telescope which scans the atmosphere vertically at a preprogrammed rate under microprocessor control. An internal calibration target is provided in the primary optics. This, together with views of cold space, provides the radiometric offset and gain.

A rotating, reflecting chopper disk is located at an intermediate focal point in the optical chain and serves both to modulate the beam at several hundred hertz and to chop it against the cold space reference. The modulated beam is then modulated again by passage through the pressure modulator cells, one in each of eight channels. Dichroic beamsplitters separate the primary beam into channels. The pressure modulators use coupled resonant pistons operating in antiphase; pressure amplitudes of 50 percent of the mean are achieved.

The detector in each channel is a four-element array in a square-shaped configuration. Each of the elements measures 2.6 km high by 18 km wide when projected on to the limb by the instrument optics. The instrument dwells between steps for typically 2 seconds to obtain signal-to-noise ratios of approximately 100:1.

A functional block diagram is shown in Figure 4-11. Table 4-5 summarizes the ISAMS instrument parameters.

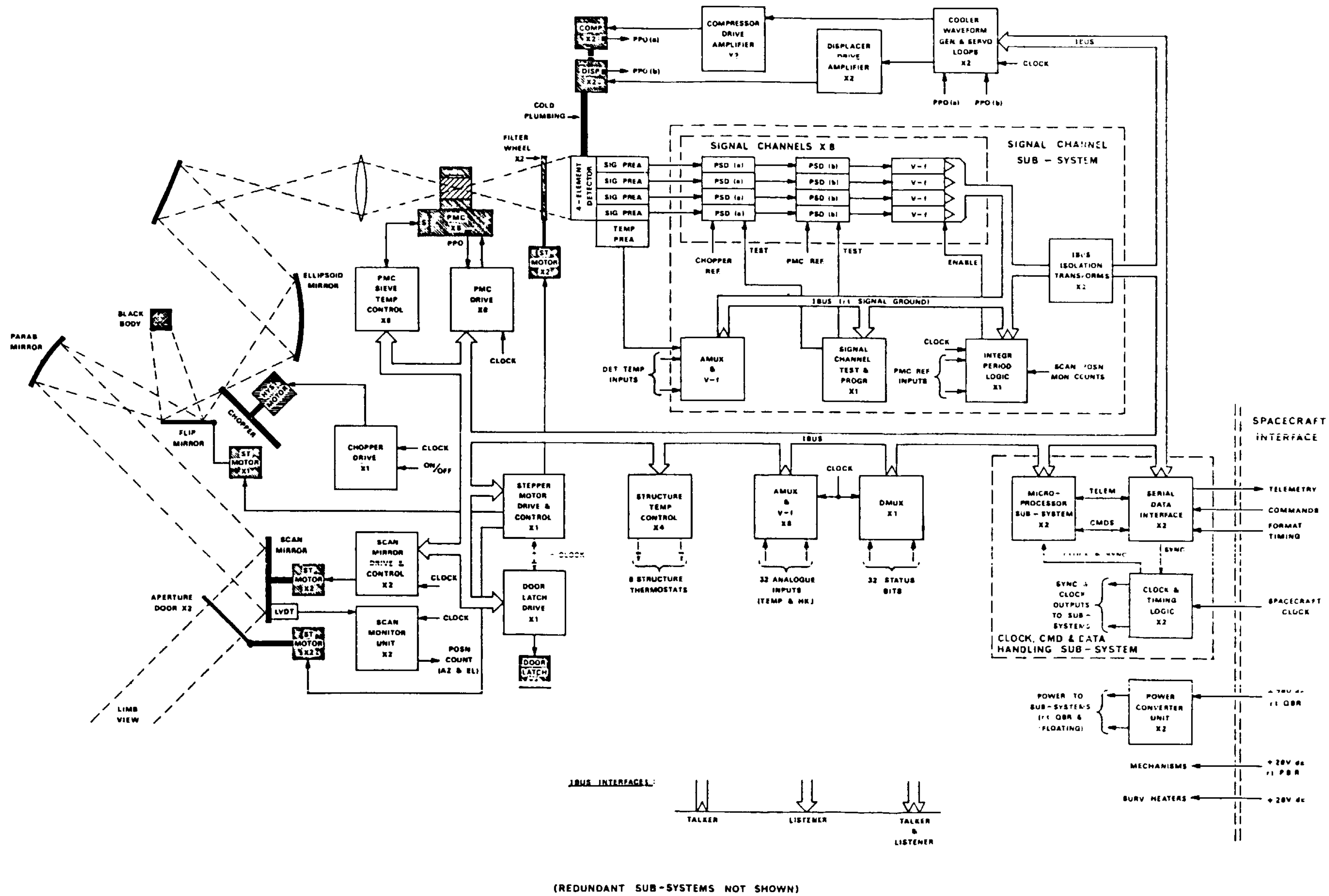


Figure 4-11. ISAMS Functional Block Diagram

Table 4-5. ISAMS Instrument Parameters

Type of measurement:	Infrared thermal emission.
Type of instrument:	Filter radiometers and pressure-modulated radiometers.
Geophysical parameters determined:	Temperature, CO, H_2O, CH_4, N_2O_5, NO, NO_2, N_2O, O_3, HNO_3, and aerosols.
Wavelength coverage:	4.6 to 16.6 microns.
Viewing geometry:	90 degrees to spacecraft velocity vector.
Maximum latitude sampled:	± 80 degrees.
Comments:	Can occasionally view toward sun side of the spacecraft.
Vertical Resolution:	2.6 km at limb.
Horizontal resolution:	18 km at limb.
Time required to perform measurement:	16 sec for 65 km vertical scan.
Distance along spacecraft track:	121 km.
Instrument weight:	385 lb.
Average power:	152 watts.
Data rate:	1.250 kbps.

4.6 Microwave Limb Sounder

Purpose

The scientific objective of the Microwave Limb Sounder (MLS) is to perform measurements which, together with those of other UARS instruments, will provide a unique data base that will test and extend present understanding of the upper atmosphere. In addition, secondary objectives include the measurement of height of pressure levels, and the measurement of one horizontal component of wind in the upper mesosphere.

The MLS ClO measurements are essential for understanding the catalytic destruction of Earth's protective ozone layer by chlorine from industrial products. The measurements of H_2O and O_3 will be very valuable for improving our understanding of chemistry and transport in the mesosphere.

Functional Description

The MLS measures atmosphere thermal emission from selected molecular spectral lines at millimeter wavelengths. Profiles of geophysical parameters are inferred from the intensity and spectral characteristics of this emission, and from its variation as the MLS line of sight is scanned vertically through the atmospheric limb.

Instrument Description

The instrument, as shown in Figure 4-12 includes the sensor, spectrometer, and power supply. The sensor includes a three-mirror antenna system that defines the field of view (FOV) plus a radiometer box that houses the radiometers, the multiplexing optics, and the calibration system.

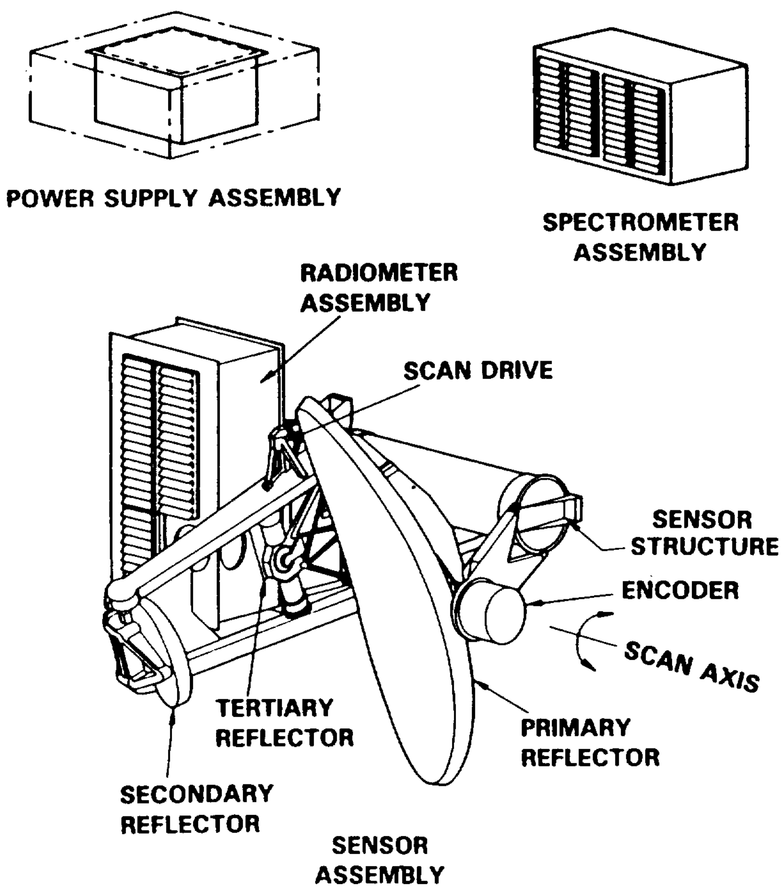


Figure 4-12. MLS Configuration

Measurements are performed continuously, day and night. The instrument integration time is 2 seconds, and a vertical scan is nominally performed in 65.5 sec or less. The FOV is in a direction normal to the UARS velocity vector. Vertical resolution for all measurements except pressure is approximately 3 km. The pressure measurement, accurate to an equivalent height of 0.1 km or better, provides the atmospheric pressure level to which the other measurements apply. Thermal control of the sensor and spectrometer is handled by radiation, using louvers. Thermal control of the power supply is handled by conduction to UARS.

The angular extent of the FOV is set by diffraction limitations of the primary mirror. The mirror's 1.6 m size in the vertical plane provides approximately 0.05 degrees vertical FOV (full width at half-power points) at 205 GHz. This provides roughly 3 km vertical resolution for the composition measurements. The antenna system is step scanned under control of an onboard program. Minimum step size is 0.05 degrees. A scan cycle including calibration is nominally performed every 65.5 seconds

A switching mirror inside the radiometer box selects either the atmospheric signal from the antenna system, the calibration from an internal target, or a zero-reference space view. The signals from the switching mirror are then spatially separated into various spectral bands by microwave optics.

The spectrometer consists of filter banks that separate the signal from each band into 15 channels. The resolution of individual channels varies from 128 MHz on the edge to 2 MHz near the center of the spectral line being measured. This resolution is matched to the characteristics of the atmospheric emission lines over the altitude range covered.

A functional block diagram of MLS is shown in Figure 4-13. Table 4-6 summarizes the MLS instrument parameters.

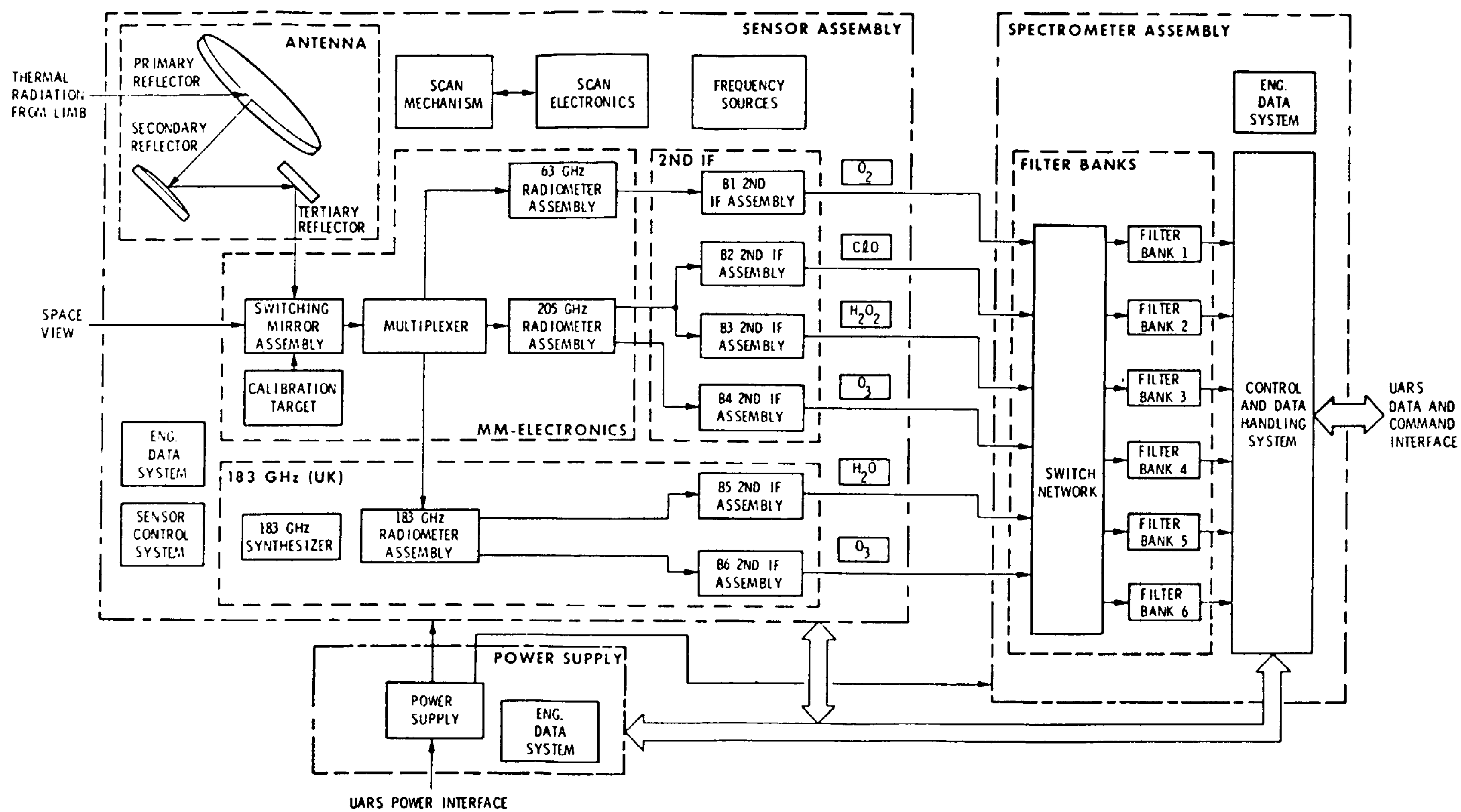


Figure 4-13. MLS Functional Block Diagram

Table 4-6. MLS Instrument Parameters

Type of measurement:	Microwave thermal atmospheric emission.
Type of instrument:	Microwave radiometer.
Geophysical Parameters Determined:	ClO, O_3, H_2O_2, H_2O, and pressure.
Frequency coverage:	63, 183, and 205 GHz.
Viewing geometry:	Atmospheric limb, 90 degrees to spacecraft velocity vector. Maximum latitude sampled: 80 degrees.
Spectral resolution:	50 MHz.
Vertical FOV:	3 to 10 km at limb.
Horizontal FOV:	10 to 30 km at limb.
Time required for vertical scan:	65.5 sec, nominal.
Distance along spacecraft track:	495 km, nominal.
Instrument weight:	626 lb.
Average power:	169 watts.
Data rate:	1.250 kbps.

4.7 Halogen Occultation Experiment

Purpose

The three fundamental goals of the Halogen Occultation Experiment (HALOE) are:

1. To improve understanding of stratospheric ozone depletion by collecting and analyzing global data on key chemical species,
2. To provide information concerning man-made versus natural causes of ozone destruction, and
3. To apply the data to the analysis of scientific questions and problems defined for UARS.

The specific scientific objectives of HALOE are:

To measure the vertical distributions of O_3, HCl, HF, CH_4, NO, NO_2, and H_2O and to prepare a global climatology for these species.

To compare vertical, geographical, and seasonal variations measured by HALOE with measurements by the SAGE instrument on AEM, and the LIMS, SAMS, and SUBV instruments on Nimbus 7.

To establish the global distribution and budgets of ozone, source molecules (CH_4 and H_2O), reservoir molecules (HCl and HF), NO, NO_2, and other species. Studies have shown that given the data provided by the eight HALOE channels, the concentrations of most of the other gases of interest can be calculated using photochemical relationships. Data from other UARS experiments (e.g., ClO, $ClONO_2$, CF_2, and $CFCl_3$ from CLAES and MLS) will be used to verify these calculations.

To use measured vertical profiles of HCl, HF, and NO to study the response of the upper atmosphere to perturbations, especially solar UV variability, solar proton events, and volcanic eruptions.

To analyze the measured data and conduct scientific investigations related to global ozone depletion, chlorine sources and sinks, stratospheric dispersion processes, latitudinal and longitudinal variability of various species, and seasonal and long-term changes in gas concentrations (e.g., HCl and HF).

To use the measured data to support refinements of multidimensional chemical and dynamics models.

Functional Description

HALOE is a solar occultation experiment designed to measure the global-scale vertical distributions of O_3, HCl,HF, CH_4, H_2O, NO, and NO_2 as a function of tangent height pressure. Pressure data will be inferred from absorption measurements obtained with a CO_2 channel. Latitudinal coverage for the 600 km, 57-degree inclined UARS orbit is from 75 degrees S to 75 degrees N. Altitude ranges are 10 to 65 km for O_3, 10 to 55 km for CH_4, 10 to 40 km for HCl and HF, and 10 to 50 km for H_2O, NO, and NO_2. The vertical resolution at the horizon is 2 km in all channels with an estimated accuracy in the mid-stratosphere of 10 to 15 percent.

The HALOE objectives will be achieved by measuring the absorption of solar energy by gaseous constituents as a function of tangent height pressure during sunrise and sunset (Figure 4-14). A vertical scan of the stratosphere is obtained by tracking the sun position during occultation. Temperature effects on the re-

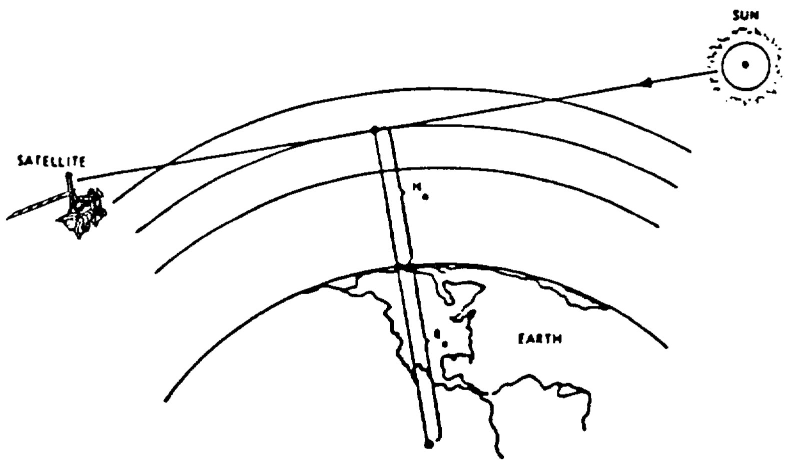


Figure 4-14. HALOE Experiment Geometry

trieval of gas concentration are second order and will be included by using climatological data. Data from the National Oceanic and Atmospheric Administration (NOAA) meteorological analysis and other satellite measurements will also be used when available.

Instrument Description

The HALOE instrument uses the gas-filter correlation radiometer technique for measurements of HCl, HF, CH_4, and NO, and broadband spectroscopy for measurement of O_3, H_2O, NO_2, and tangent height pressure (CO_2). The principle of gas-filter correlation radiometry is illustrated schematically in Figure 4-15. Solar energy enters the sensor and is divided into two paths. The first path contains a cell filled with the gas to be measured (e.g., HCl, HF, NO, CH_4), the second is a vacuum path. An electronic gain adjustment is used in one detector circuit. This adjusts the signal output so that the two electro-optical paths are matched when there is no target gas in the intervening atmosphere. When the target gas is present in the atmosphere, the

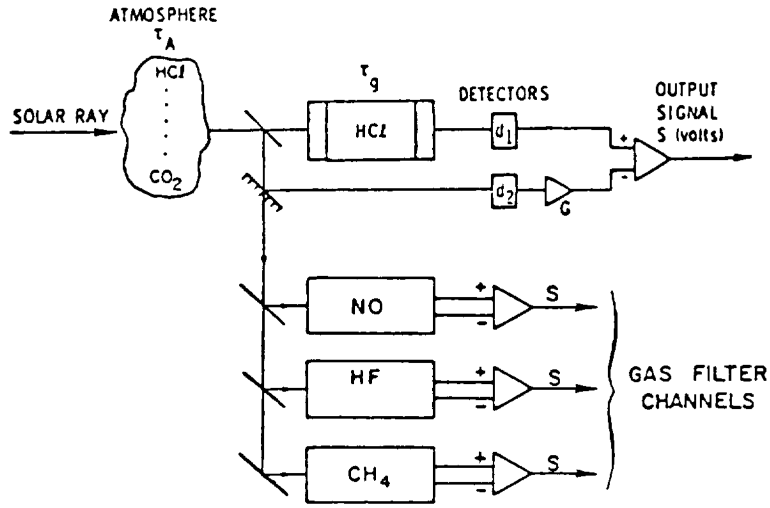


Figure 4-15. HALOE Gas Filter Correlation Technique

spectral content of the incoming energy is correlated with the absorption line spectrum in the gas cell. This correlation upsets the matched condition, causing a signal difference that is proportional to stratospheric HCl, HF, NO, or CH_4 concentration. A CH_4 attenuation cell is included in front of both the vacuum and the gas cell paths to minimize the sensitivity of the HCl measurement to interfering CH_4 absorption. The radiometer channel data are reduced to atmospheric transmission data by taking the ratio of occultation data to data taken outside the atmosphere. The transmission data are then used to retrieve mixing ratio as a function of pressure.

As shown in Figure 4-16, the HALOE instrument consists of an optics unit supported on a two-axis gimbal and an off-gimbal electronics unit. The optics unit contains the optics, modulators, detectors, and preamps for all gas detection channels. A 16-cm diameter reflective Cassegrain telescope collects solar energy for all channels. A field stop at the focal point of the telescope de-

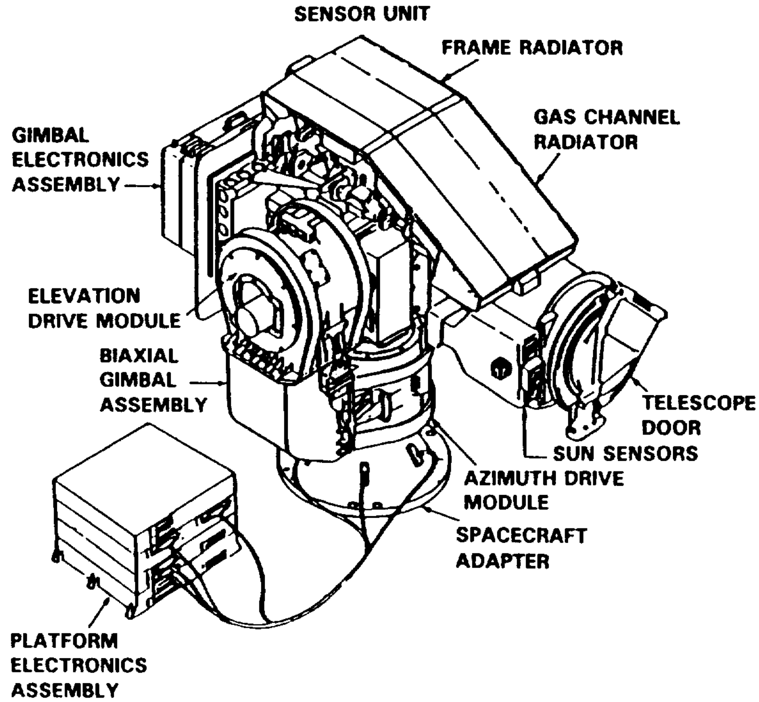


Figure 4-16. HALOE Configuration

termines the instantaneous field of view of the instrument. The incoming solar energy is chopped at 150 Hz using a reflective chopper: reflected energy is directed to the radiometer channels; nonreflected energy is directed to the gas filter channels. A second optical signal from a blackbody reference is chopped at 300 Hz to maintain the exo-atmospheric gain balance in the gas filter channels during occultation. After passing through the chopper the nonreflected optical beam is separated by beamsplitters into the four gas filter channels. The gas concentration data for each event are determined by applying inversion techniques to the processed signals from these channels and the processed signals from the radiometer channels.

A stepper-driven calibration wheel is located behind the telescope field stop to provide periodic measurements of gas response, radiometric calibration, and instrument balance, using the exo-atmospheric sun as an energy source. The calibration wheel contains eight gas cells and three neutral density filters for in-flight scale factor and linearity calibration checks.

The stepper-driven, two-axis gimbal assembly (azimuth and elevation) supports the optics unit near its center of gravity. The gimbals provide a capability for fine tracking with tracking control signals derived from the sun sensors.

The off-gimbal electronics unit provides signal processing, motor drives, sequence timing, mode control, power conditioning, and data handling. This unit is the major electrical interface between the spacecraft and the HALOE instrument.

A functional block diagram of HALOE is shown in Figure 4-17. Table 4-7 summarizes the HALOE instrument parameters.

Table 4-7. HALOE Instrument Parameters

Type of measurement:	Solar occultation, infrared atmospheric absorption.
Type of instrument:	Gas correlation and filter radiometers.
Geophysical Parameters determined:	HF, HCl, CH_4, NO, H_2O, O_3, NO_2, and pressure (CO_2).
Wavelength coverage:	2.43 to 10.25 microns.
Viewing geometry:	Spacecraft sunrise and sunset.
Spectral resolution:	2 km at limb.
Horizontal resolution:	6.2 km at limb.
Instrument weight:	204 lb.
Average power:	134 watts.
Data rate:	4.0 kbps.

4.8 High Resolution Doppler Imager

Purpose

The High Resolution Doppler Imager (HRDI) is designed to study the dynamics of the Earth's atmosphere from UARS.

The output of the instrument is horizontal-vector wind fields. Accuracy is better than 5 meters per second over prescribed regions of the atmosphere extending from the upper troposphere through the thermosphere. The data will be used in a comprehensive study of the dynamics of the atmosphere and the dynamic coupling between the various regions of the atmosphere.

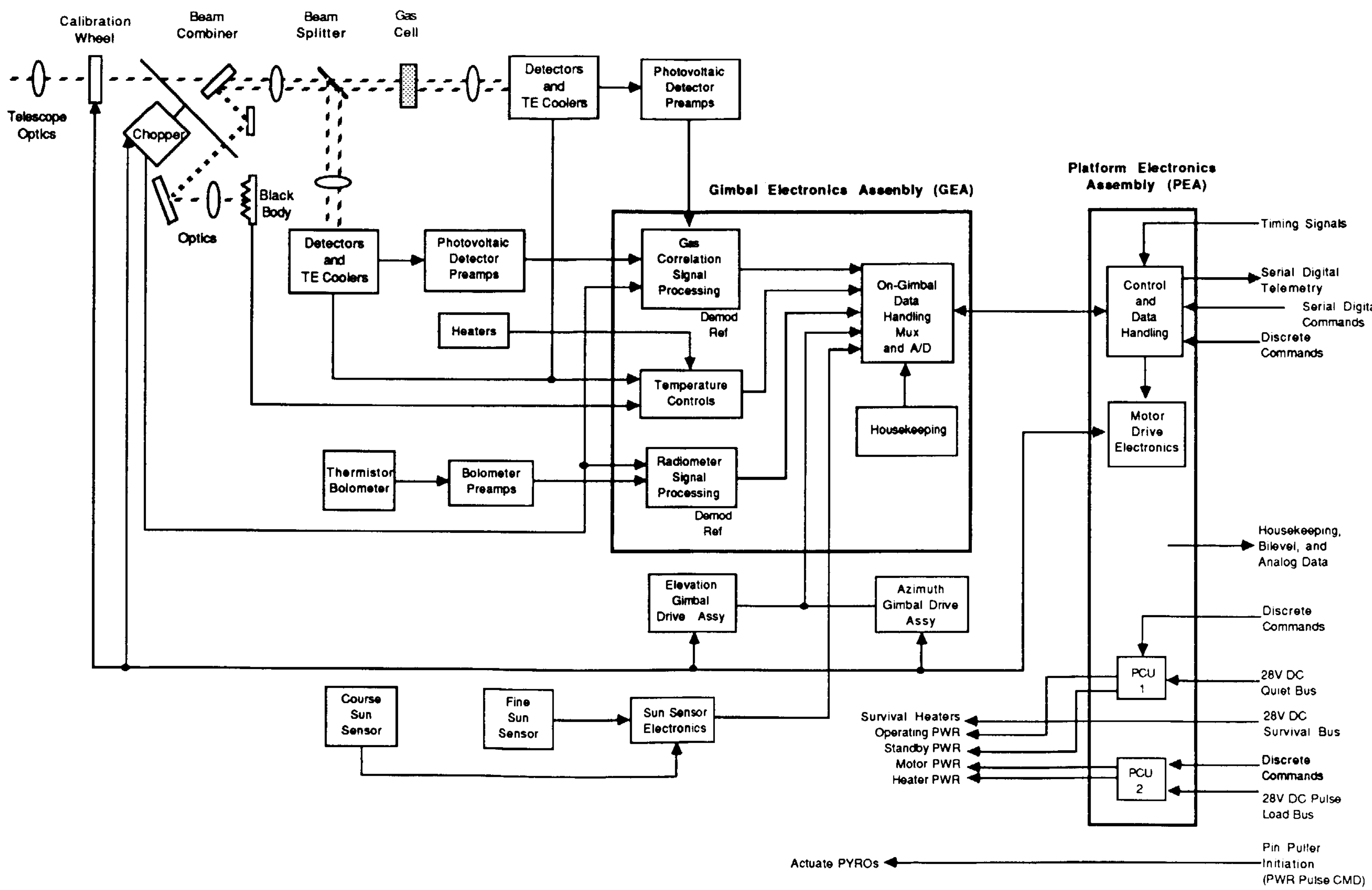


Figure 4-17. HALOE Functional Block Diagram

Functional Description

The HRDI instrument is a stable, triple-etalon, high-resolution Fabry-Perot interferometer that views the Earth's atmosphere through a two-axis, gimbaled telescope. The instrument performs wavelength analysis on the light detected from atmospheric emission or absorption features by spatially scanning the interference fringe plane with a multichannel array detector. A sequential altitude scan performed by the commandable telescope provides global coverage of the thermodynamic state of the atmosphere from cloud top through the thermosphere. HRDI is the first orbiting instrument to use this measuring technique.

Instrument Description

The HRDI instrument, as shown in Figure 4-18, consists of the two-axis, gimbaled telescope, triple-etalon Fabry-Perot interferometer, interferometer electronics, support electronics, and a dedicated instrument processor.

The telescope consists of a well-baffled off-axis parabola telescope mounted on a two-axis gimbal structure. This provides the ability to point anywhere within a hemisphere, to measure wind vectors at various altitudes.

The interferometer assembly consists of an optical bench, interferometer optics, and support electronics. The bench is supported by kinematic mounts.

Interferometer optics:

Relay optics provide input from the telescope subassembly.

Two eight-position filter wheels select spectral regions of interest.

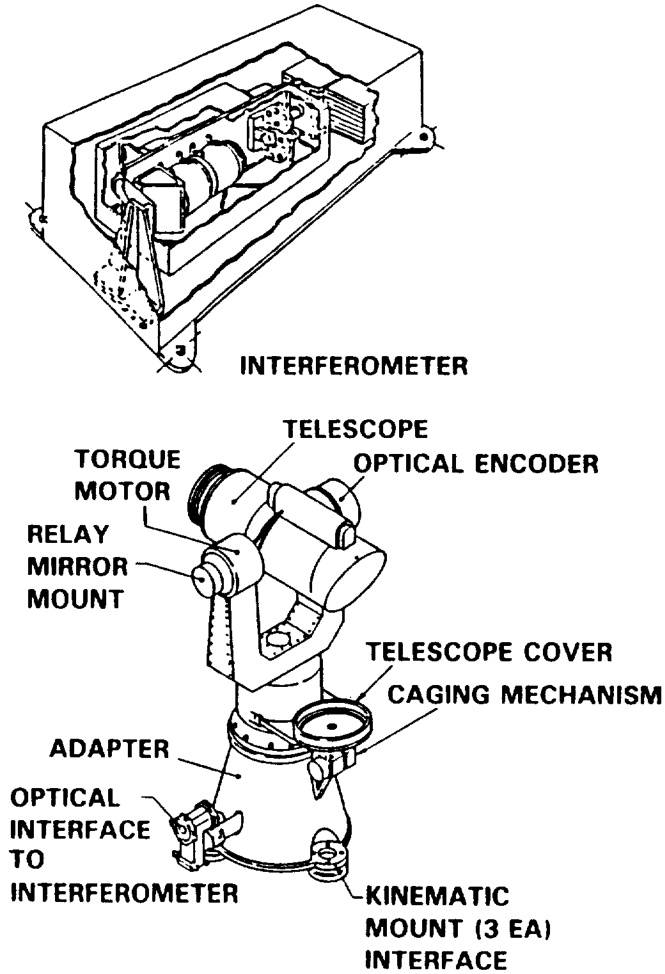


Figure 4-18. HRDI Configuration

The multiple-etalon Fabry-Perot design provides white light rejection and high throughput, allowing measurement of absorption features. The low-resolution etalon and medium-resolution etalon use piezoelectric spacers to tune gap spacing between the etalons.

The piezoelectric spacers are controlled by feedback circuits commanded by the dedicated instrument processor. Etalons for the interferometer are 132 mm in diameter with 90 mm clear field of view.

The folding mirrors reduce overall length of the instrument thereby reducing weight.

The interferometer's ruggedized Questar telescope focuses interference patterns received from the high-resolution etalon onto the image plane detector.

The image plane detector is a modification of the design flown on the Dynamics Explorer Satellite, but has a larger anode array consisting of 32 concentric ring elements. The anode array converts the ring pattern of photons (produced by the etalons) into sets of discrete electron pulses representing spectral elements.

Electronics within the instrument provide power, telemetry, command, and logic functions. The dedicated instrument processor controls instrument functions including telescope positioning, filter selection, and etalon control.

A functional block diagram of HRDI is shown in Figure 4-19 Table 4-8 summarizes the HRDI instrument parameters.

Table 4-8. HRDI Instrument Parameters

Type of measurement:	Doppler shift and line broadening of scattered sunlight and atmospheric emission in the visible wavelengths.
Type of instrument:	Triple-etalon Fabry-Perot interferometer.
Geophysical Parameters determined:	Horizontal-vector wind and atmospheric temperature.
Wavelength coverage:	400 to 800 nanometers.
Viewing geometry:	45 degrees, 135 degrees, 225 degrees, and 315 degrees ± 5 degrees to spacecraft velocity vector.
Maximum latitude sampled:	74 degrees.
Comments:	Gimbaled telescope provides potential for viewing any azimuth direction; orthogonal measurements for same atmospheric volume separated by approximately 8 minutes.
Spectral Resolution:	0.001 nanometers.
Vertical Resolution:	6 km at limb (0.12 degree field of view).
Horizontal resolution:	80 km at limb (1.7 degree field of view).
Time required for one vertical scan:	7.33 sec for 90 km scan.
Distance along spacecraft track:	55 km per scan. Potential of four vertical scans of vector wind in 500 km along track.
Instrument weight:	348 lb.
Average power:	109 watts.
Data rate:	4.750 kbps.

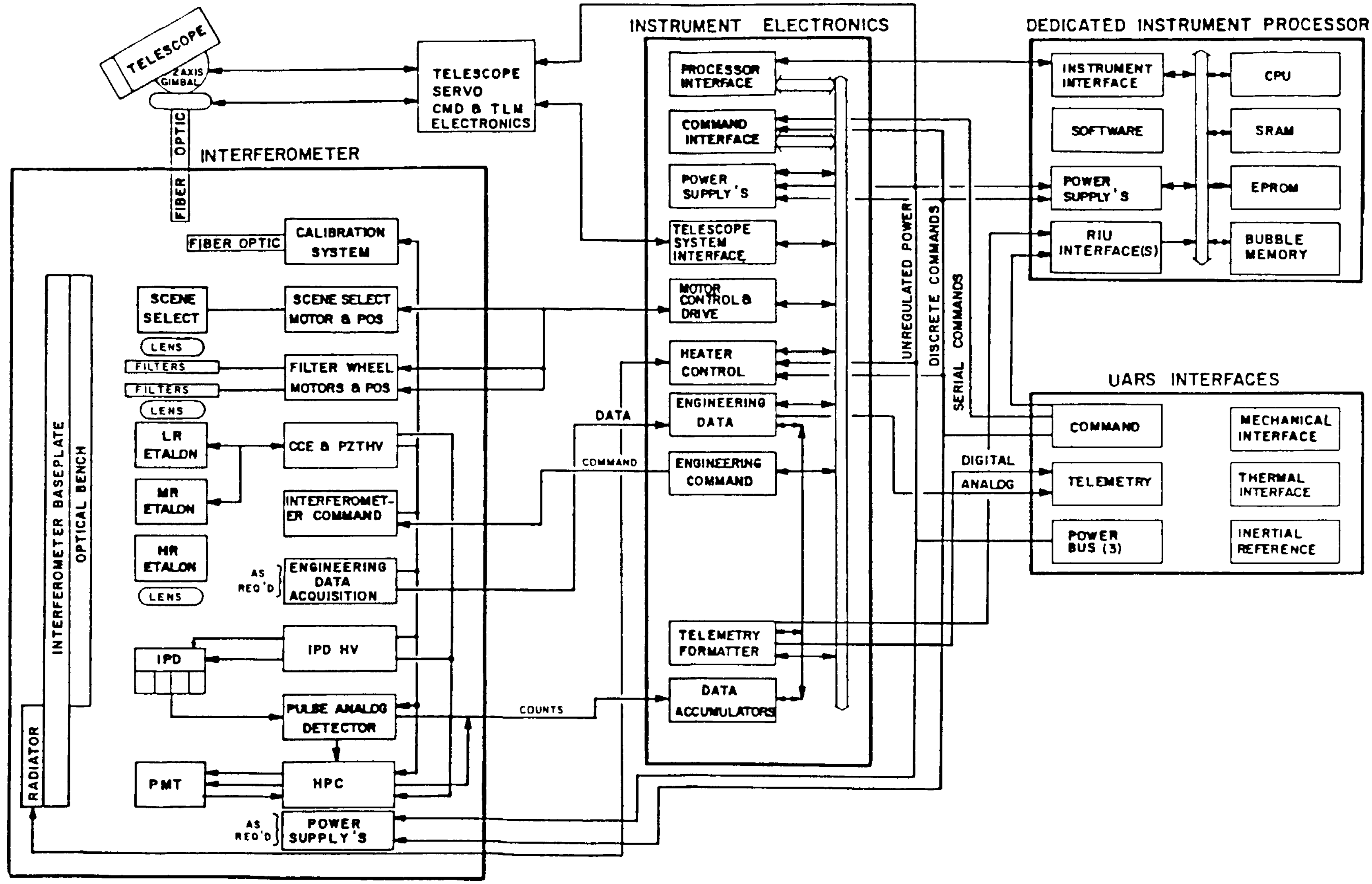


Figure 4-19. HRDI Functional Block Diagram

4.9 Wind Imaging Interferometer

Purpose

The Wind Imaging Interferometer (WINDII) senses temperatures and winds in the mesosphere and the lower thermosphere by measuring both Doppler widths and shifts of isolated spectral lines. These are emitted by the airglow and aurora.

The three principal objectives for the WINDII experiment are:

1) To measure two-dimensional vertical profiles of the horizontal wind velocity and Doppler temperature of the neutral atmosphere in the altitude range 70 to 315 km, and to determine these profiles as functions of latitude, time of day, and time of year,

2) To measure the global distribution of small-scale wave-like structures, down to a scale size of 3 km, and

3) To study dynamic and thermal aspects of the neutral atmospheric energy balance in the observed altitude range.

Functional Description

The instrument views the atmospheric limb simultaneously in two directions, 45 degrees and 135 degrees from the velocity vector; due to the spacecraft motion, these cover the same atmospheric region with a time delay of a few minutes. This provides both horizontal components of the neutral wind. An imaging detector provides simultaneous measurements of temperature and wind profiles over the instrument's entire altitude range. The detector also provides the required resolution to observe the small wave-like structures.

Instrument Description

As shown in Figure 4-20, the instrument consists essentially of a CCD camera viewing the Earth limb through a field-widened Michelson interferometer. The instrument takes four images, with the interferometer optical path difference changed by 1/4 wavelength between images. Analysis of these images provides fringe phase (leading to wind velocity), fringe modulation depth (leading to temperature), and emission rate. A field combiner in the input optics positions the two orthogonal fields of view side by side on the CCD so that both views are simultaneously recorded.

The Michelson optics consist of a cemented glass hexagonal beamsplitter, a glass block with a deposited mirror in one arm of the interferomenter, and a glass block combined with an air gap and a piezoelectrically driven mirror in the other arm. The mirror position is controlled through capacitive sensing to provide stability and accurate stepsize.

The CCD camera consists of a fast camera lens and an RCA 501E CCD cooled to -50 degrees C. The imaging area has 320 by 256 pixels with a corresponding storage area that the image is shifted into after the exposure. During readout, binning and windowing techniques select desired altitude ranges, and tailor the image to the available telemetry rate.

To isolate specific spectral lines, interference filters are mounted in a temperature-controlled filter wheel assembly.

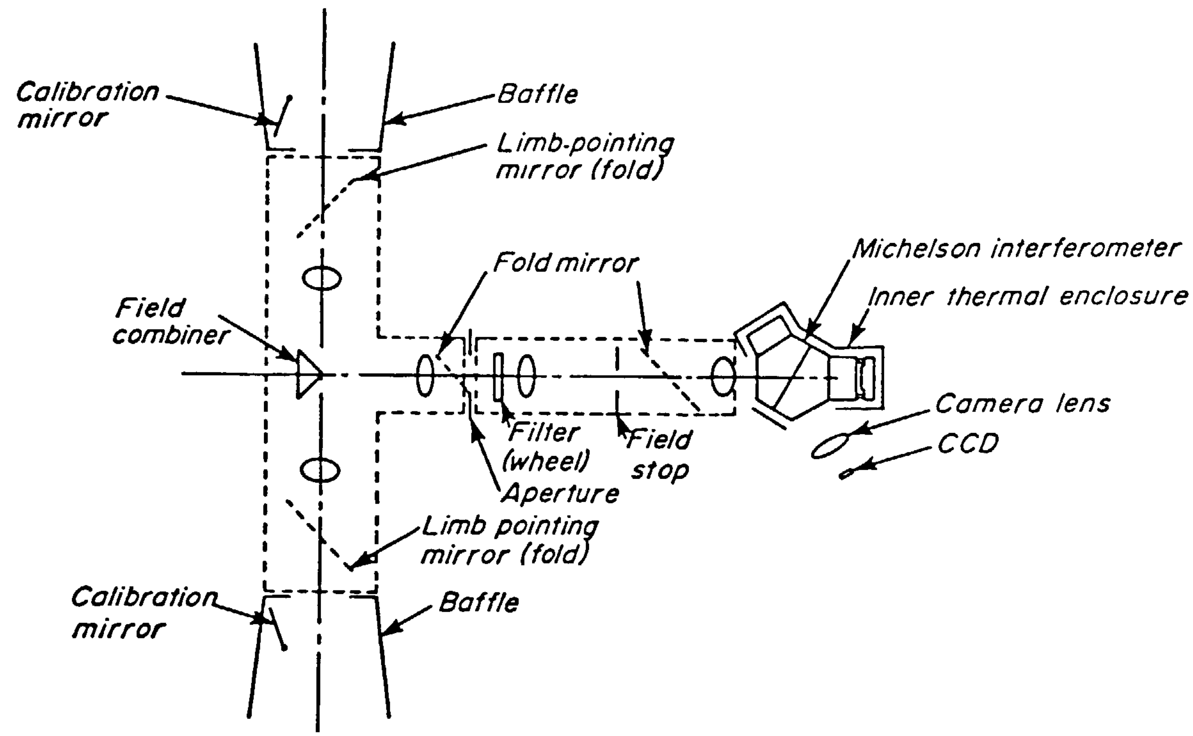


Figure 4-20. WINDII Optical Schematic

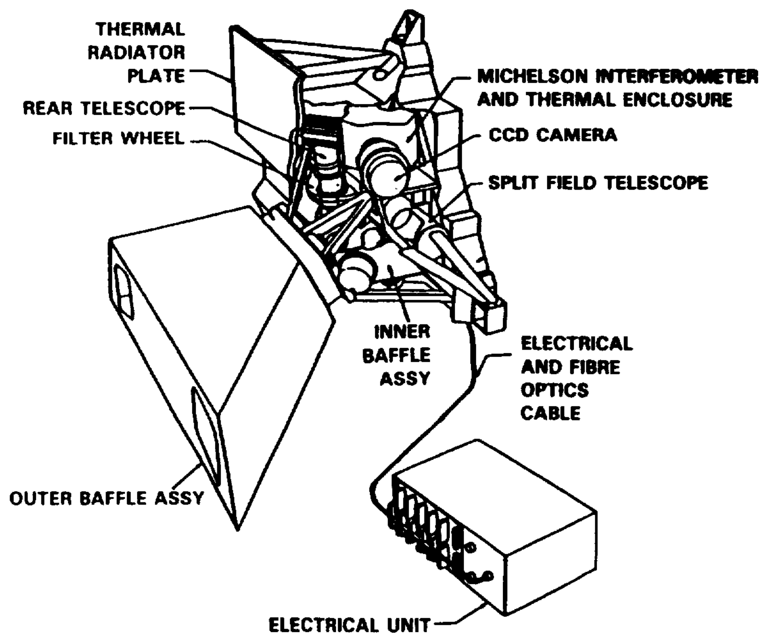


Figure 4-21. WINDII Configuration

The two telescope inputs are designed to eliminate stray light, to transform the field of view to the desired value, and to provide a suitable location for the beam combiner. A schematic diagram of the optical layout is shown in Figure 4-21. This optical train contains the filter wheel, a mirror for calibration sources, and an aperture stop-down to provide lower scattered light levels for daytime viewing. A one-meter long baffle tube is used in each input. These baffles intersect to fit within the available space.

A separate calibration box contains radio frequency excited spectral lamps, a tungsten lamp, and a He-Ne laser. The spectral lamps are used for frequent phase calibration, the tungsten lamp for infrequent responsivity calibrations, and the laser for infrequent visibility calibrations.

An internal microprocessor controls all the instrument functions including camera control, filter wheel control, thermal control, and control of all other mechanisms. Buffer memory exists for additional onboard processing of the image data before the data are sent to telemetry.

A WINDII functional block diagram is shown in Figure 4-22. WINDII instrument parameters are summarized in Table 4-9.

Table 4-9. WINDII Instrument Parameters

Type of measurement:	Doppler shift and line broadening of atmospheric emission in the visible and near infrared.
Type of instrument:	Field-widened Michelson interferometer.
Geophysical Parameters Determined:	Atmospheric temperature and horizontal wind vector.
Wavelength coverage:	550 to 780 nanometers.
Viewing geometry:	45 degrees and 135 degrees to spacecraft velocity vector. Maximum latitude sampled is 74 degrees.
Comments:	Orthogonal measurements for same atmospheric volume separated in time by approximately 8 minutes.
Vertical field of view:	6 degrees, 70 to 315 km at the horizon.
Vertical resolution:	4 km at horizon (nominal). 1.5 km at horizon (potential).
Horizonal resolution:	20 km (along track) at horizon.
Time required to perform measurement is 8 sec. Distance along spacecraft track is 60.5 km.	
Instrument weight:	269 lb.
Average power:	73 watts.
Data rate:	2.0 kbps.

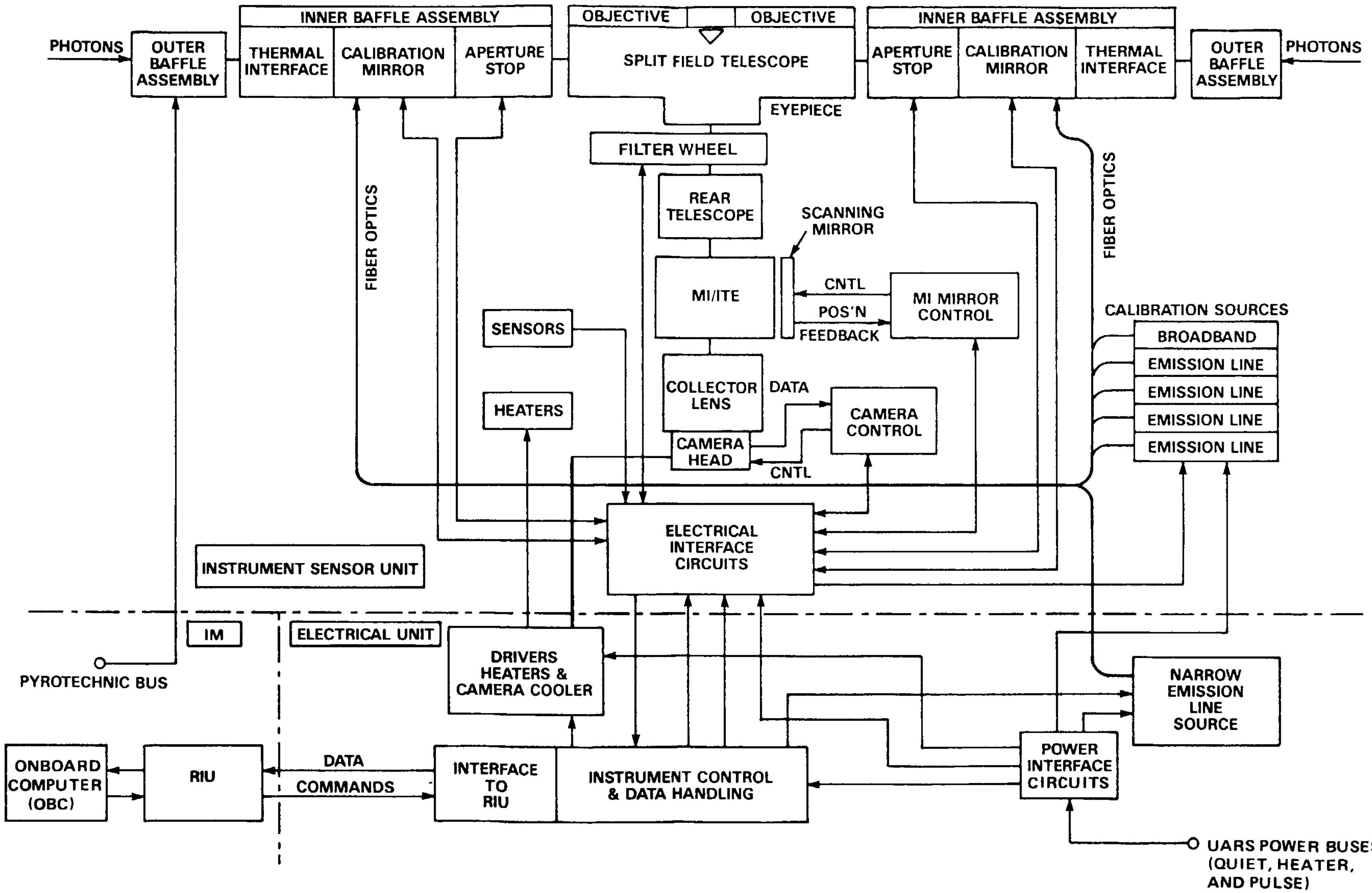


Figure 4-22. WINDII Functional Block Diagram

4.10 Active Cavity Radiometer Irradiance Monitor

Purpose

The objective of the Active Cavity Radiometer Irradiance Monitor (ACRIM II) is to conduct precise solar total irradiance monitoring during a period of expected increasing solar activity, approaching the maximum for Solar Cycle 22. The ACRIM II measurements will aid both climatological and solar physics investigations.

The ACRIM II instrument, located on the UARS Solar Stellar Pointing Platform (SSPP), will be an important component of the long-term solar irradiance monitoring by the National Climate Program. This program is studying solar irradiance variability and its effect on weather and climate over at least one solar magnetic cycle (about 22 years).

Functional Description

ACRIM II is designed for the continuous measurement of solar total irradiance with uniform sensitivity from the far-ultraviolet to the far-infrared wavelength range with an absolute uncertainty in the International System of Units of 1%, a single sample resolution of 0.012%, and a multiyear internal precision of 5 ppm.

Instrument Description

The ACRIM II instrument will use three Active Cavity Radiometer (ACR) pyrheliometers of the advanced Type V design. The overall ACRIM II configuration is shown in Figure 4-23. The modular design allows for the electronics and sensor module to be mounted separately.

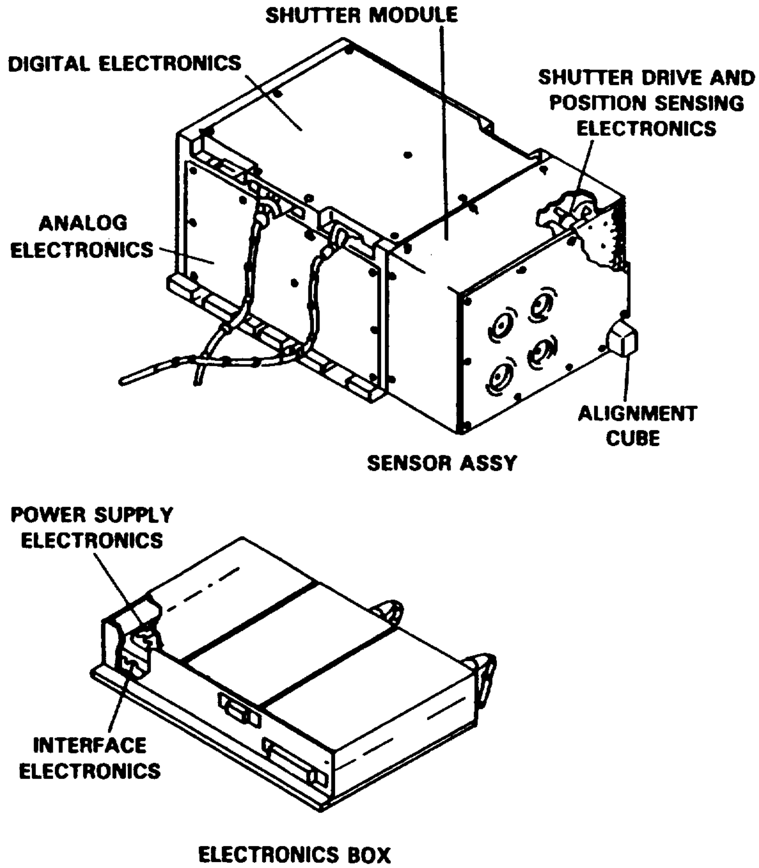


Figure 4-23. ACRIM II Configuration

The design of the Active Cavity Radiometer (ACR) Type V pyrheliometers is shown in Figures 4-24 and 4-25. Two right-circular conical cavity detectors are thermally connected to the heat sink through their respective thermal impedances. The interiors of the cavities are coated with a specular black paint. A low-temperature-coefficient heater winding is bonded to the top of each thermal impedance, near the cavity apertures. The primary cavity is irradiated through a precisely machined and accurately measured primary aperture. The detector's field of view is de-

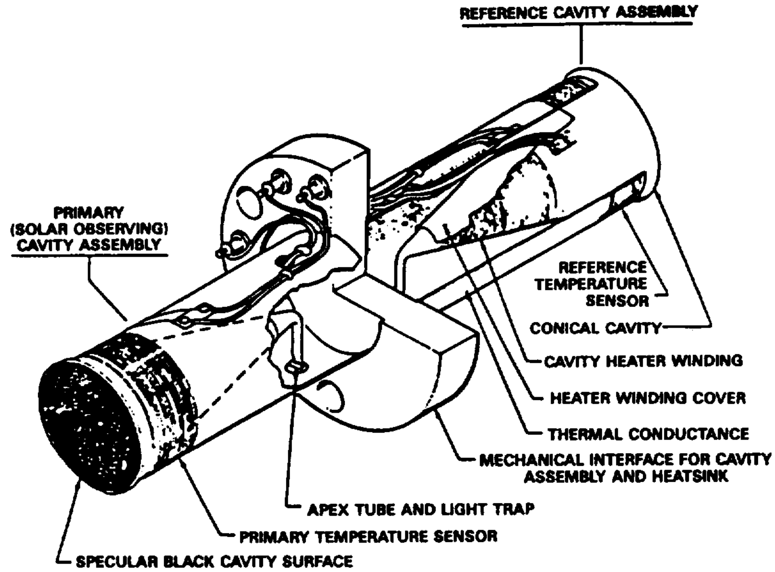


Figure 4-24. ACRIM II ACR Type V Cavity Assembly

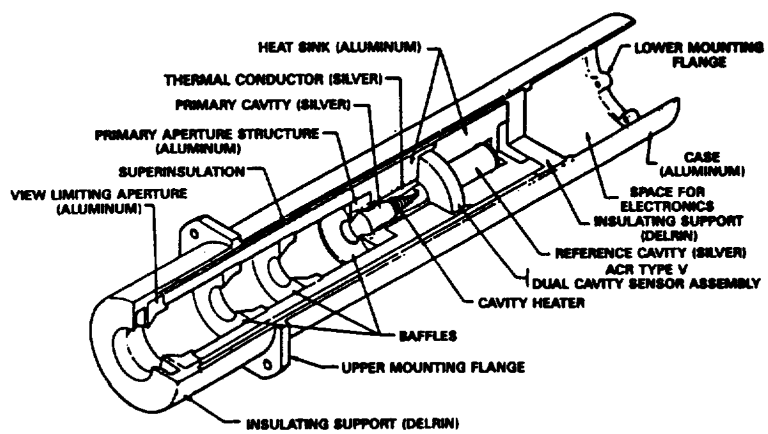


Figure 4-25. ACRIM II ACR TYPE V Detector Module

fined by the secondary (view limiting) aperture that is at the top of an extension of the heat sink. The heat sink assembly is insulated from the outer case. There are three baffles between the primary aperture and the view limiter. These are thermally connected to the heat sink. Their purposes are to minimize solar heating of the primary aperture and to prevent the primary cavity from viewing the internal walls of the view limiting extension of the heat sink.

The dissipation of a fixed amount of power in each primary cavity produces a constant temperature drop across the thermal impedance. This drop, transduced by the resistance temperature sensors, is used by an electronic servo system to automatically maintain constant cavity power dissipation by controlling the DC voltage supplied to the cavity heater. The primary cavity detector of the ACR is accurately maintained at a slightly higher temperature than the heat sink at all times.

The ACR operates in a differential mode. A shutter alternately blocks solar radiation from, and admits it to, the primary cavity. In the shutter closed phase, or reference phase, of the measurement, the ACR views its own heat sink. In the shutter open phase, or observation phase, the ACR views the sun. Electrical heating provides the power to balance the cavity's conductive and radiative losses, thereby maintaining a constant cavity-to-heat-sink temperature difference. When viewing the sun, the power supplied by the electronics automatically decreases by an amount proportional to the solar irradiance of the cavity aperture. Absolute irradiance measurements are derived from the difference in the electrical power supplied in the two phases of measurement.

Figure 4-26 shows the functional block diagram for the ACRIM II instrument. Electrical interface to the UARS is made through a Remote Interface Unit (RIU) on the SSPP. Commands to, and all data from, the ACRIM II instrument are transmitted via the RIU. Table 4-10 summarizes the ACRIM II instrument characteristics.

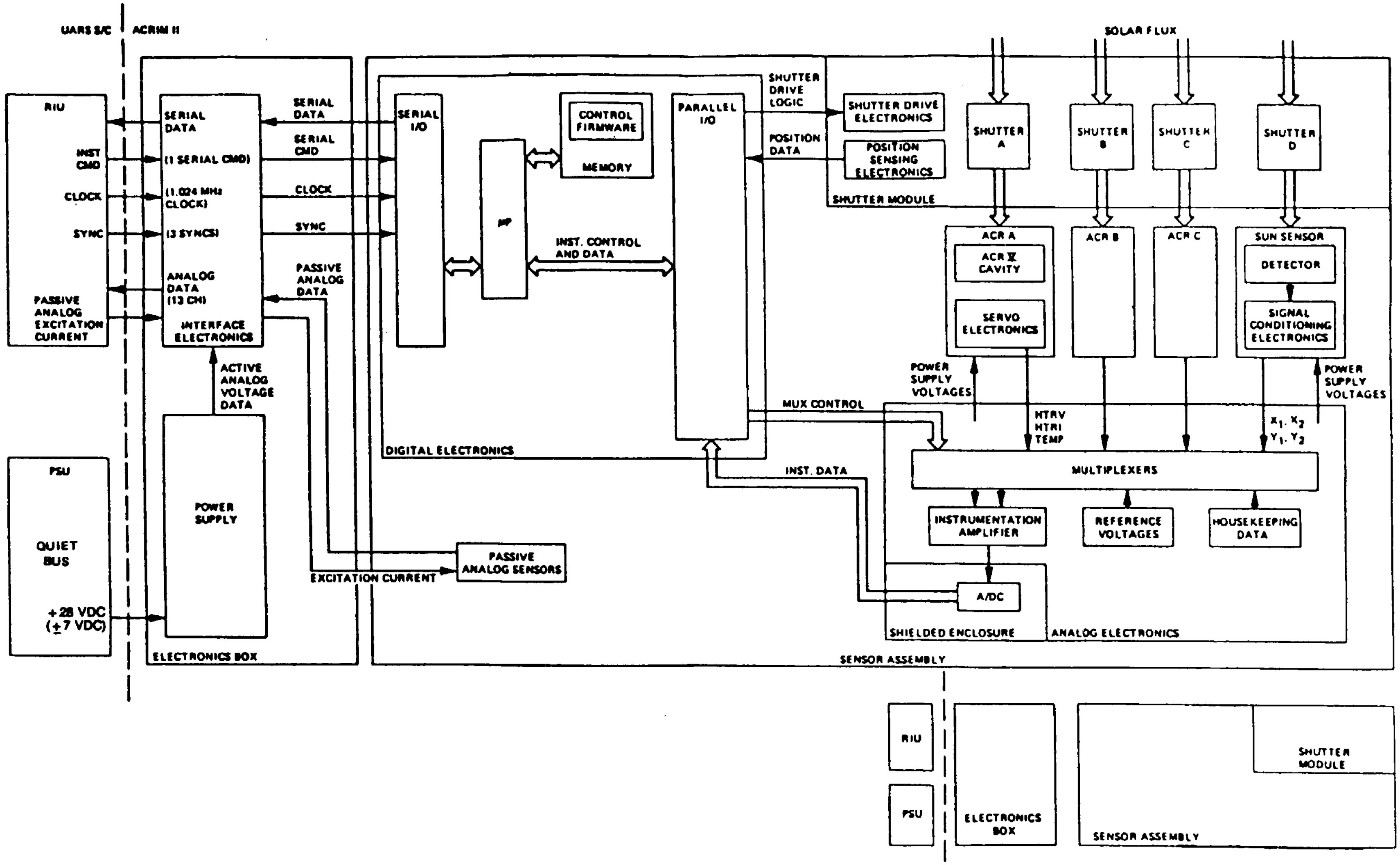


Figure 4-26. ACRIM II Functional Block Diagram

Table 4-10. ACRIM II Instrument Parameters

Type of measurement:	Precise solar total irradiance.
Type of instrument:	Three Type V Active Cavity Radiometers, one sun position sensor.
Parameter determined:	Measures solar total irradiance, 0 to 2000 watts per square meter. Measures instrument solar alignment with 0.1 degrees resolution.
Wavelength coverage:	0.001 to 1000 microns.
Accuracy:	99.9% at solar total irradiance level.
Precision:	0.012% of full scale for single samples. Phased operation of sensors for stand-alone calibration of degradation yields precision better than 0.005%, over 1-year periods.
Field of view:	5 degrees with 1-degree tolerance for solar pointing.
Instrument weight:	52 lb.
Average power:	5 watts.
Data rate:	0.5 kbps.

SECTION 5
FLIGHT OPERATIONS

Section	Page

5. Flight Operations

5.1 Overview

5.1.1 Mission Highlights

The UARS observatory is designed to collect a coordinated set of measurements that will expand scientific knowledge of the Earth's upper atmosphere. UARS flight on-orbit fall into four categories. They are:

Launch and Deployment by the Space Transportation System (STS) from Kennedy Space Center (KSC) in the fall of 1991. After thorough testing of the UARS observatory in the STS payload bay, the observatory will be removed from the payload bay and deployed by means of the STS Remote Manipulator System (RMS).

Activation and Alignment during the first month of operation in orbit. All of the instruments collecting science data will be activated and then tested. On-orbit alignment verification and calibration will be initiated.

Normal orbit operations for data collection. Following activation and alignment, instrument operation will be coordinated to provide a comprehensive set of atmospheric measurements.

Maneuvers to yaw the spacecraft, to maintain proper altitude, and to control attitude. Yaw maneuvers are needed to avoid direct sun on sensitive instruments. Attitude control maneuvers are needed to properly position UARS for scientific measurements. Drag make-up maneuvers will keep the spacecraft at the proper altitude. The flight operations will be controlled and monitored by the UARS ground system located at GSFC.

5.1.2 Operations Philosophy

The UARS Project operations philosophy is based on two important principles:

Active participation of each instrument investigator and the spacecraft development contractor. Due to the complex nature of the UARS spacecraft, such participation will be required for effective operation of the observatory.

Coordination of flight operations activities and instrument operation will be essential to ensure that the science program satisfies the UARS Project science objectives.

5.1.3 Operations Flow

UARS flight operations, as shown in Figure 5-1, will be guided by a Long-Term Science Plan. This plan will be developed by the Science Team, which includes each UARS Principal Investigator. The Science Team is chaired by the UARS Project Scientist, and meets periodically at GSFC. The Flight Operations Team for UARS will support science planning activities by serving as the spokesman for capabilities and constraints of both the ground system and spacecraft.

Daily Science Plans will be developed by a science-oriented Mission Planning Group, under the direction of the Project Scientist, and in conjunction with the instrument investigators. The Daily Science Plan for instrument control will contain all the information needed for command generation. Daily science planning will be performed at GSFC on a normal work-week schedule, such that each plan will be available several days in advance to allow for review and revision.

These plans will be filed in the Command Management System (CMS) computer at GSFC and will be available by telecommunications to Remote Analysis Computers (RACs) at various investigator locations. The CMS computer will also serve as the repository for spacecraft operations planning and scheduling aid information.

The PIs will provide command, command sequence, and generic timing information to the CMS for scheduling. Using the schedule information developed by the instrument investigators, the CMS will generate commands to control UARS observatory operations. These commands will follow the Daily Science Plans. The CMS will perform validity and constraint checks. It will also provide processed command timelines for review at GSFC and at Remote Analysis Computer locations.

The Project Operations Control Center (POCC) is located at GSFC. The POCC will be the focal point for on-orbit operations and will be manned around the clock, seven days per week, by the flight operations team. The POCC will uplink commands prepared by the CMS, and will verify successful uplink. The desirability of limiting routine uplink activity to once per day yields a project goal of 24-hour on-board autonomy. If necessary, specific commands can be generated by the POCC through keyboard input.

Instrument health and safety will be monitored by the Flight Operations Team during all real-time contacts. However, each instrument investigator must monitor the performance of his instrument, and each investigator is responsible for any troubleshooting or on-board software maintenance related to his instrument. Investigators will be able to access POCC displays by telecommunications to remote KCRT terminals. Recorded telemetry playback data will normally be available to Remote Analysis Computers within one or two days. One quick-look tape playback will be available on each eight-hour work shift within one hour after receipt at GSFC. Each instrument investigator is also responsible for maintaining ground system data base information for his instrument, and for insuring that performance knowledge is properly factored into plans for ongoing operations.

5.2 Ground System Description

Ground system facilities for UARS flight operations will include a combination of GSFC institutional facilities and mission unique facilities. The operational system is shown in Figure 5-1.

The Project Operations Control Center (POCC), Command Management System (CMS), and Flight Dynamics Facility (FDF) computer systems are interconnected by computer-to-computer links for UARS data transfers. Figures 5-1 through 5-5 show the various interfaces as well as the functions of the ground elements. The Software Development and Validation Facility (SDVF) will exchange data with the GSFC facilities over a dedicated communication line provided by the NASA Communications Network (NASCOM). The Data Capture Facility (DCF) will respond to POCC requests for data from the telemetry archive using magnetic tape. Science and mission planning personnel will interface with the CMS using local CMS terminals. Investigators have access to the CMS through the Remote Analysis Com-

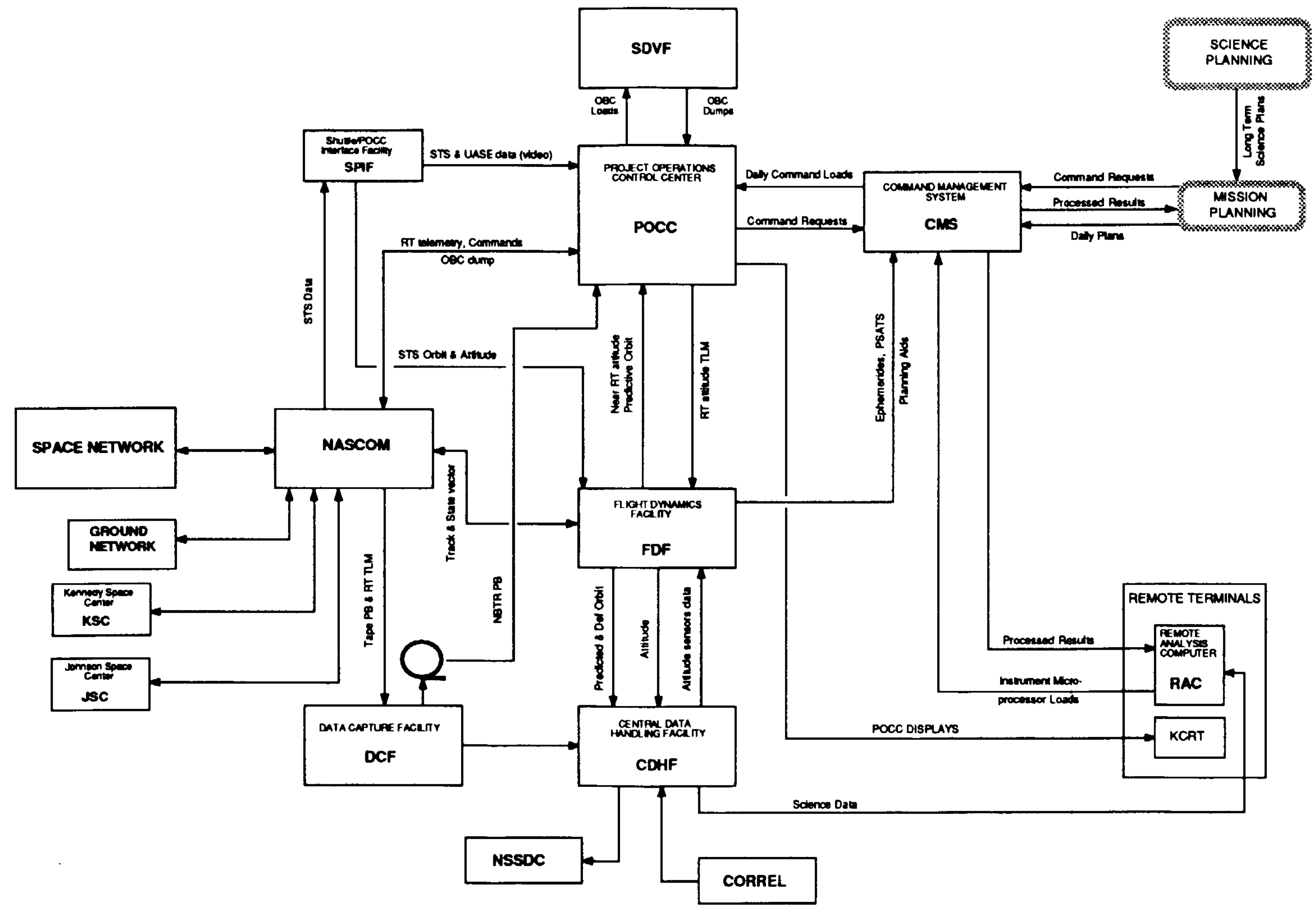


Figure 5-1. UARS Ground System Operational Block Diagram

puter (RAC) link to the Central Data Handling Facility (CDHF). The POCC KCRTs located at investigator facilities connect directly into the POCC computer system through dial-up modem ports.

5.2.1 Institutional Elements

Several NASA institutional elements will provide routine support for UARS.

The Space Network (SN) will provide primary RF communications to and from the orbiting observatory through the Tracking and Data Relay Satellite (TDRS) S-band Single Access (SSA) or S-band Multiple Access (SMA) service. The network will also provide UARS tracking information in the form of time-marked range and range rate.

The NASA Communications Network (NASCOM) will provide communications among all the NASA ground elements, including communications between the NASA Ground Terminal (NGT) at White Sands, New Mexico, and various ground system elements located at GSFC. NASCOM will also provide communications between Johnson Space Center (JSC) and Kennedy Space Center (KSC) ground elements and GSFC ground elements. NASCOM and the Space Network resources are scheduled by the Network Control Center (NCC) located at GSFC.

The Program Support Communications Network (PSCN) will provide computer-to-computer communications between the investigators' Remote Access Computers (RACs) and the Central Data Handling Facility (CDHF) at GSFC.

The Project Operations Control Center (POCC), located at GSFC, will use the facilities of the Multi-Satellite Operations Control Center (MSOCC). The POCC will serve as the focal point for all UARS operations. It will be manned by the Flight Operations

Team (FOT) and will be the primary interface with the UARS Observatory for command and telemetry. The POCC will also function as the center for health and safety of the observatory, and for coordination of all activities necessary for achieving mission objectives. During the UARS mission, the UARS POCC will share the facilities and services of the MSOCC with other satellite missions.

The Command Management System (CMS) will generate the stored command load and instrument microprocessor loads and will send these loads to the POCC for transmission to the observatory. The CMS will maintain a database of instrument and spacecraft commands, command sequences, and microprocessor loads for the generation of daily operational commands. It will provide tools and planning aids to users to facilitate planning and command generation, and it will automatically perform validity and constraint checks on command requests.

The Flight Dynamics Facility (FDF) will determine observatory orbit and attitude, and will provide maneuver planning and analysis support to Flight Operations. The FDF will receive tracking information from Space Network, through NASCOM, for use in computation of UARS definitive and predicted orbit information. The FDF will provide, through the CMS, the daily UARS and TDRS ephemerides and UARS star catalogs for upload to the spacecraft. The FDF will also provide planning aids for use by the Flight Operations Team (FOT) and Mission Planning Group (MPG) in daily planning. UARS Observatory telemetry will be provided to the FDF to facilitate the computation of spacecraft attitude. Support for instrument alignment verification, orbit maneuvers, and performance and calibration of the Attitude Determination and Control Subsystem (AD&CS) will be provided as needed.

The Data Capture Facility (DCF) will collect telemetry data for science-oriented processing, and will archive playback data for possible use by the Flight Operations Team. The DCF will provide the first level of processing by reversing sequence, eliminating redundant data, and cataloging. The DCF services are shared with other spacecraft missions.

The Kennedy Space Center (KSC) and STS Mission Control Center-Houston (MCC-H) will provide support during prelaunch, launch, and deployment operations. The UARS observatory will be launched aboard a NASA Space Transportation System (STS) launch vehicle from the Kennedy Space Center (KSC) in Cape Canaveral, Florida. The STS will be under the control of the STS Mission Control Center (MCC-H) located at NASA Johnson Space Center (JSC) in Houston, Texas. Prelaunch operations will include considerable testing of the interfaces between the UARS observatory, STS, KSC, and POCC. During prelaunch, launch, and deployment operations, all commanding to and telemetry from UARS will be routed through the MCC-H.

The Shuttle/POCC Interface Facility (SPIF), located at GSFC, will provide communications and STS-unique data handling support through UARS launch and deployment. The SPIF will also provide interface testing and simulation support during prelaunch checkout. The SPIF will provide STS orbital, attitude, and ancillary data to the FDF for further processing. The FDF will use the data to generate initial ephemerides and to provide special display information to the POCC during launch and deployment.

5.2.2 Project-Unique Elements

Other ground system elements provide special support for the UARS mission. These elements include:

The Central Data Handling Facility (CDHF), located at GSFC, is a project-unique ground data processing system that will handle all centralized processing of UARS science data. The CDHF is described in detail in Section 6.

The Software Development and Validation Facility (SDVF), located at the spacecraft contractor's site in Valley Forge, Pennsylvania, will be used for on-orbit anomaly analysis as well as maintenance and update support for spacecraft computer software. The SDVF will develop and verify on-board computer software changes before forwarding them to the POCC for upload to the spacecraft. The SDVF will also have access to all POCC displays through a KCRT linked by modem to the POCC.

A Remote Analysis Computer (RAC) and POCC Computer Terminal (KCRT) will be located at each instrument investigator facility. These will be used for operational support and data analysis. The RACs will be used for flight operations purposes to provide each instrument team with the means of updating the CMS data bases and to provide access to current plans and planning aids. PIs will also use the RACs to submit command sequences and instrument microprocessor loads to the CMS. The KCRT will let PIs view telemetry from the observatory during real-time contacts.

The UARS Test and Training Simulator (UTTS) will be available for testing the ground system and training the Flight Operations Team (FOT). The UTTS will be able to simulate nominal operation of the UARS spacecraft as well as anomalies. It will be used extensively during prelaunch to validate the system and train the FOT. The UTTS will also be used to validate the flight plan, procedures, and data bases.

5.3 Roles and Responsibilities

Specific roles and responsibilities of the UARS Flight Operations participants are as follows:

The Mission Operations Manager is responsible for developing requirements for, and for the management of, that portion of the ground system supporting flight operations. After launch, he will be responsible for the operation of the observatory. The Mission Operations Manager will work closely with the Project Scientist, Data Systems Manager, and the Flight Operations Manager.

The Project Scientist is responsible for meeting the science objectives of the mission and for ensuring the timely availability of processed data. The Project Scientist will chair the Science Team and the Mission Planning Group.

The Science Team will consist of all the UARS Principal Investigators (PIs), the UARS Project Scientist, and a representative from the Flight Operations Team. It will be chaired by the UARS Project Scientist. The Science Team will create all science-oriented long-term plans to meet science mission objectives.

The Mission Planning Group (MPG) will be responsible for all operations-oriented planning, and will coordinate the daily science plans with the long-term science plans. The MPG will be made up of science personnel, mission operations personnel, and spacecraft operations personnel. It will be directed by the Project Scientist. The MPG will use the CMS-provided planning aids in the production of daily science plans. The MPG will also coordinate the instrument investigators' data base. This data base will contain instrument command loads, instrument microprocessor loads, and instrument constraints.

The Instrument Investigators will provide CMS data base inputs of command sequences, microprocessor loads, or both, as appropriate. These will be used to control instrument operation, maintain instrument microprocessor software, and verify instrument operational performance. Each investigator will advise the MPG and Science Team of the performance analysis and evaluation of his instrument.

The Flight Operations Team (FOT) will conduct on-orbit operations, and will staff the POCC twenty-four hours per day, seven days per week. The FOT will be responsible for the performance of the spacecraft, coordination of data base maintenance, and coordination of command activities associated with operations. The FOT will provide the UARS Science Team and the Mission Planning Group with support regarding capabilities and constraints of both spacecraft and ground system. The FOT will also provide prelaunch support in the form of testing and training to ensure readiness for on-orbit operations. Figure 5-2 shows the composition of the FOT.

The Mission Operations and Data Systems Directorate (MO&DSD) will provide the ground system for UARS flight operations and centralized ground data processing. In addition, the MO&DSD will provide a training simulator and will provide support for mission analysis to determine launch time, optimum orbit, orbit decay, network coverage, and observatory attitude. The MO&DSD may use a mission contractor to provide these services.

5.4 Normal Operations

5.4.1 Routine Planning

Routine planning for the UARS mission is a multi-phase process. The process is part of a consistent, coordinated system designed to meet the UARS mission goals. Briefly, a Long-Term Science Plan will establish guidelines for achieving mission objectives. Daily Science Plans will define the UARS instrument

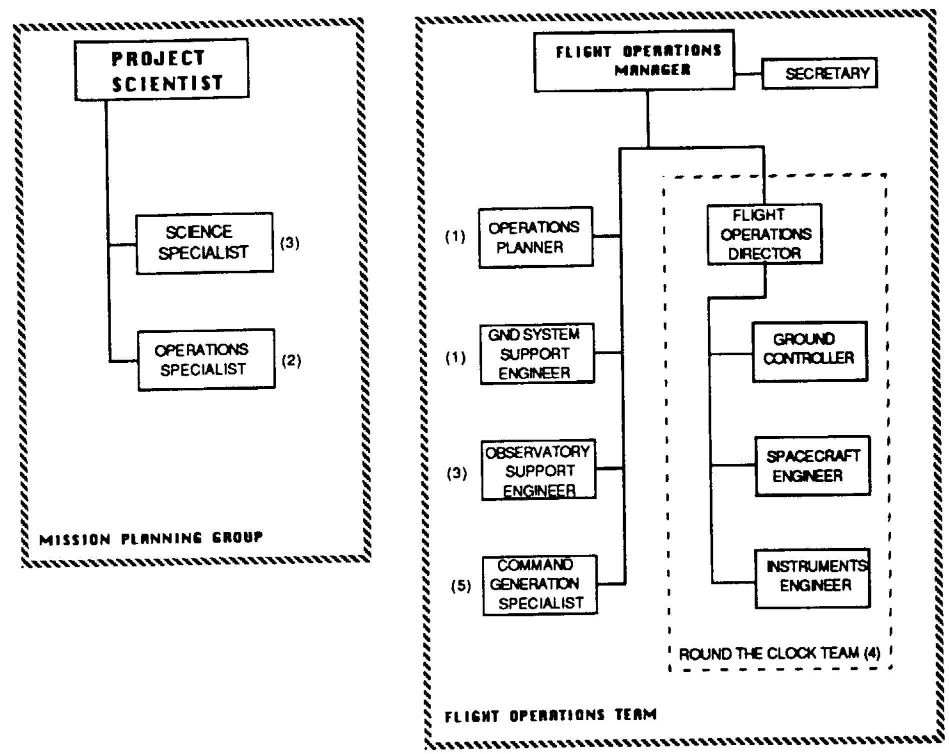


Figure 5-2. UARS Flight Operations Team Composition

activities needed to satisfy the long-term science goals. Daily Operations Plans will incorporate the daily science activities and will define the observatory functions needed to support those activities. A typical 96-minute orbit is shown in Figure 1-11.

5.4.2 Mission Planning

Mission planning, to establish the goals and objectives for the full UARS mission, will be an ongoing procedure that will be continually revised and refined. Mission planning will be performed by the UARS Mission Planning Group at NASA Goddard Space Flight Center (GSFC). A Long-Term Science Plan will then be created by the UARS Science Team to reflect the UARS mission planning objectives.

5.4.2.1 Long-Term Science Planning

The Long-Term Science Plan will consist of:

science goals for the UARS mission,

guidelines for daily planning,

preferred approaches for satisfying UARS scientific objectives,

requirements for coordination between the instruments, and

definitions of special events.

The Long-Term Science Plan will be updated periodically to reflect then-current capabilities of the UARS observatory and ground system. For example, the Long-Term Science Plan will be updated during the first month of the UARS mission to reflect the actual launch parameters and initial orbital performance. Later updates will accommodate any observed degradation or other changes in instrument or spacecraft capabilities.

5.4.2.2 Daily Planning

Daily Operations Plans will define the instrument and spacecraft activities needed to collect mission science data on a daily basis. The Mission Planning group will prepare the Daily Operations Plans by following the guidelines of the Long-Term Science Plan. The Daily Operations Plan will consist of ten separate instrument science plans, a Solar Stellar Pointing Platform (SSPP) science plan, and a spacecraft operations plan. The Mission Planning Group will coordinate each Daily Science Plan with the instrument Principal Investigators (PIs) and the Flight Operations Team (FOT). This process will insure that the Daily Operations Plan is consistent with current observatory and instrument constraints. Figure 5-3 shows a flow of the planning process.

5.4.3 Command Generation

Command generation is the process through which Daily Operations Plans are converted into real-time commands, instrument microprocessor instructions, and stored commands. Also included in command generation are spacecraft and TDRS ephemeris table loads. The Command Management System (CMS) at GSFC will serve as the focal point for this process.Each instrument PI will have access to the CMS through a Remote Analysis Computer (RAC). The FOT will have access to the CMS through dedicated CMS terminals. In addition to generating commands and ephemeris tables, the command generation process will create activity plans, activity lists, and integrated schedules (see Figure 5-4).

Activity Plans

The command generation process will begin with the creation of activity plans by the Mission Planning Group. These plans consist of lists of activities (e.g.,

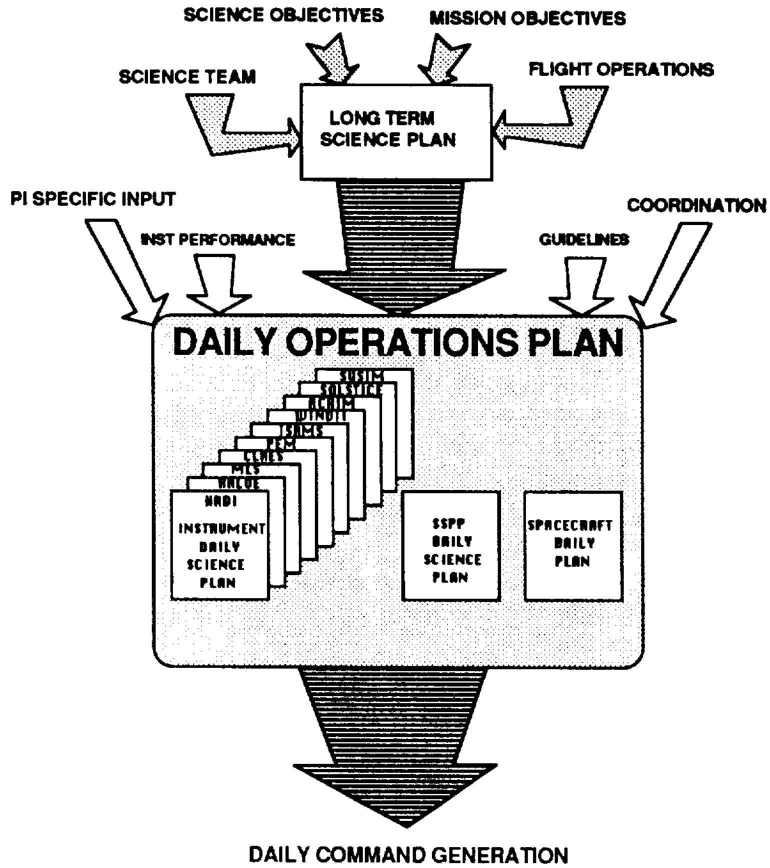


Figure 5-3. Flight Operations Planning Flow

normal daylight scan) and corresponding generic times for these activities (e.g., 5 minutes before sunset). The activity plans will be entered into the CMS where they can be reviewed by the PIs.

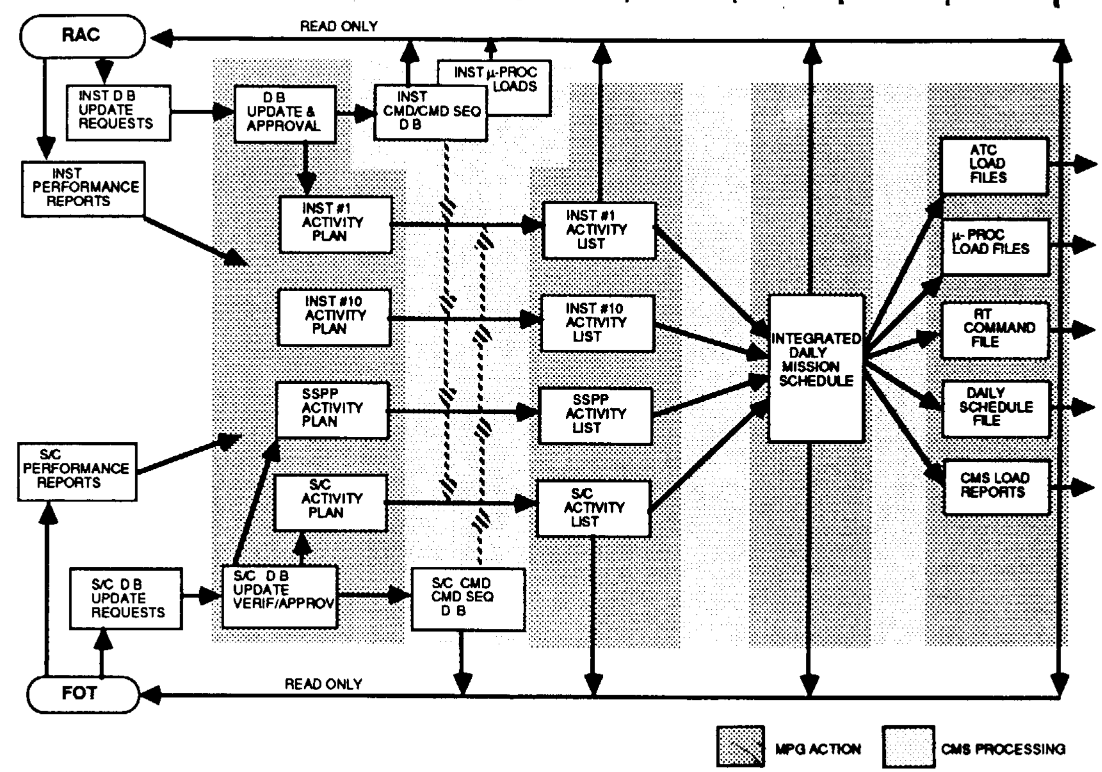


Figure 5-4. UARS Command Generation Process

Activity List

The CMS will generate an activity list by converting the activity plans into specific commands or instrument microprocessor loads. These will be placed in the correct time sequence with specific time-tags. For example, if an activity plan entry is for a measurement to be taken every orbit, the activity list will include the specific actions associated with that measurement and will time-tag those actions to occur during each of the 15 orbits for that day.

Ephemeris

Daily command generation will include the generation of the spacecraft and TDRS ephemeris tables. The CMS will convert ephemeris data from the FDF into an OBC table load by processing the data with the correct time parameters. The CMS will then forward the OBC ephemeris table load to the POCC for upload to the observatory.

Integrated Schedule

After completing the final activity lists for each of the instruments, for the Solar Stellar Pointing Platform (SSPP), and for spacecraft operations, as well as generating the ephemeris table loads, the CMS will generate a comprehensive activity list. This will be an integrated schedule for the operation of the UARS spacecraft, subsystems, and instruments. The integrated schedule will coordinate all elements created by the command generation process.

Command Output

The output of the command generation process will include stored commands, instrument microprocessor load files, spacecraft and TDRS ephemeris table loads, and real-time command files, all of which will be uplinked to the UARS spacecraft. In addition, the command generation process produces a set of procedures, schedules, and plans for implementation by the FOT.

5.4.4 Real-time Operations

The Flight Operations Team will conduct real-time operations from the UARS POCC. Real-time operations will be dictated by the availability of the Space Network. TDRS communication will be scheduled in advance by the Network Control Center located at GSFC, and TDRS contact times will be incorporated into the Daily Operations Schedule.

The Daily Operations Schedule will be generated from the Integrated Schedule, and will be a listing of generic activities scheduled for the UARS observatory. This schedule will be used to organize the POCC activities.

A typical Daily Operations Schedule will call for one real-time contact per orbit to verify the health and safety of the instruments and spacecraft, and to retrieve recorded telemetry data. In addition, the real-time contact will be able to acquire tracking data as required. Uplink operations (which include the stored commands loads, instrument microprocessor loads, and ephemeris loads) are sent once a day during an orbit contact.

The daily uplink message schedule will routinely include one stored command load and one or more ephemeris loads. It may also include one or more instrument microprocessor loads or a star catalog input. Non-routine real-time activities will be added to the daily operations schedule by the FOT as needed (see Figure 5-5).

REAL-TIME OPERATIONS

- 15 MINUTE CONTACT ONCE/ORBIT:
  - Tape recorder playback (each contact)
  - Ranging (as required)
  - Commanding (goal of one stored load per day)
  - Performance monitoring (throughout)
  - OBC memory verification (as required)

- COMMANDING:

TYPE	SOURCE	R/T VERIFY (POCC)
Real-Time	POCC	Execution
Stored	CMS	OBC Dump
Ephemerides/ Star Catalog (Obsv, TDRSS)	FDF (via CMS)	OBC Dump
Instrument microprocessor	RAC (via CMS)	Command count
OBC Memory	SDVF	OBC Dump

- PERFORMANCE MONITORING:
  - POCC processes/displays 32 kbps (or 1 kbps) telemetry
  - FDF provides near R/T attitude (Obsv, HGAS, SSPP)
  - POCC computes/displays observatory attitude
  - POCC monitors/acts to preserve health & safety of observatory & instruments
  - POCC displays are accessible to PI via KCRT
  - POCC records/processes one playback per day for trend analysis
  - POCC processes/displays 32 kbps OBC dump

Figure 5-5. Real-time Contact Operations

The POCC computer system will initiate and monitor the transmission of each uplink message to the observatory. Any real-time command that performs a critical spacecraft function (i.e., firing a pyrotechnic device) will require confirmation before implementation. The POCC computer system will also process incoming real-time telemetry data and will generate appropriate displays throughout each real-time contact. Telemetry processing in the POCC will include decommutation and calibration, conversion to engineering units, interpretation of discrete parameters, limit checks of analog parameters, and generation of alarm messages to alert operations personnel to predefined telemetry indications.

Periodically, real-time attitude sensor data from UARS will be provided to the FDF so that UARS attitude knowledge can be determined in near real-time. This data will be available at the POCC through video displays from the FDF. The instrument PIs will be able to monitor real-time contact to display selected instrument data. The PIs will have access through four dial-up modems in the POCC, using the KCRTs located at the PI facilities.

In each real-time contact, initial priority will be given to establishing reliable communications links to and from the observatory. Once the communication links are established, the UARS tape recorders will be given the command for playback. Other real-time activities will be performed after the initiation of tape recorder playback. POCC displays will be used to monitor health and safety of the UARS subsystems and instruments. In the event of anomalous instrument health and safety indications, the FOT will initiate commands to the observatory to correct or minimize the apparent problems.

5.4.5 Post-contact Follow-up

Post-contact Operations will assess the performance of the instruments and spacecraft, and will establish baseline data for trend analysis and anomaly investigation. These operations include extraction of specified data from telemetry playbacks, generation of history files for use in trend analysis, evaluation of spacecraft operation and instrument performance, and preparation of periodic status and performance reports. The POCC will process one telemetry playback per day for post-contact operations.

The DCF will provide quick-look data by processing one playback each eight-hour shift. The quick-look data will be available for instrument evaluation by the PIs through access to the CDHF.

5.4.6 Special Observations

Unique opportunities to make special observations of scientific interest are likely to arise during the UARS mission. These might include the effects of a volcanic eruption or a significant solar flare. In such instances, special procedures will be invoked to take advantage of the opportunity at hand. The Mission Planning Group will be the focal point for initiating such procedures. Activity plans and activity lists for these special opportunities will be generated in a manner similar to that used for generating the daily procedures and plans.

5.5 Special Operations

5.5.1 Launch and Deployment

The UARS Observatory will be launched on the NASA Space Transportation System (STS). Beginning with launch, there will be 5 operational phases for the UARS. The 5 phases are:

STS Launch
Post-Insertion
Payload In-Bay Checkout
Deployment
Post-Release

Figure 5-6 shows a mission timeline for Launch and Deployment.

5.5.1.1 Launch and Deployment Ground System Configuration

The ground system configuration during launch and deployment is unique to those phases, because the POCC must interface with the UARS through the Space Transportation System (STS). All commands from the POCC must be sent through the STS by way of the Johnson Space Center (JSC) Mission Control Center-Houston (MCC-H), and all telemetry from the UARS must be sent through the STS orbiter communication systems, to the MCC-H, and forwarded to the GSFC ground facilities.

Data that comes from the STS orbiter is called the STS orbiter downlink. This consists of STS data, special UARS Airborne Support Equipment (UASE) data, and UARS telemetry. The MCC-H strips out the UARS data and the UASE data, so it can treat each of the three sets of data separately. It then packs each set of data into blocks of 4800 bits, suitable for NASCOM, and sends these blocks over the NASCOM data network (see Figure 5-7). These data blocks will be processed by separate facilities at GSFC. The POCC, SPIF, and FDF are equipped to process the downlinked NASA data blocks.

The Project Operations Control Center (POCC) will receive and process the UARS telemetry data blocks. Once at the POCC, the UARS telemetry will be converted to engineering units and will be displayed to verify commands sent to the spacecraft.

The Shuttle/POCC Interface Facility (SPIF) will receive and process blocks of STS orbiter data and blocks of UASE data from the NASCOM network. The SPIF will convert the UASE data into engineering units and will provide video displays of this data to the POCC. In

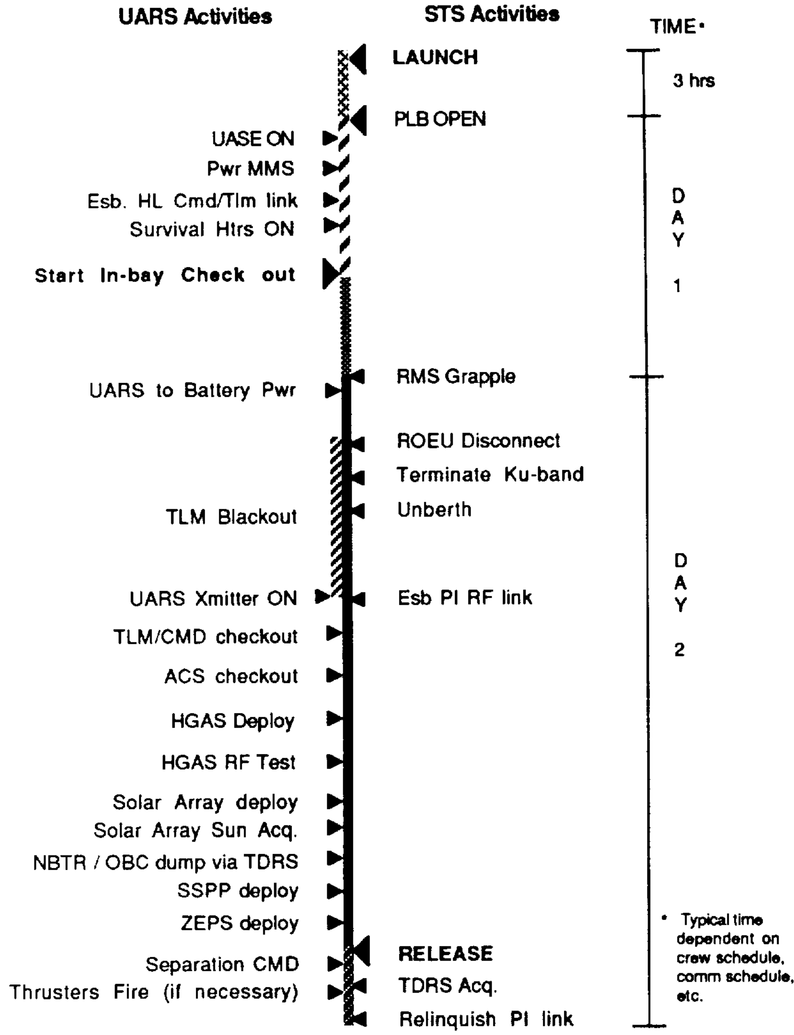
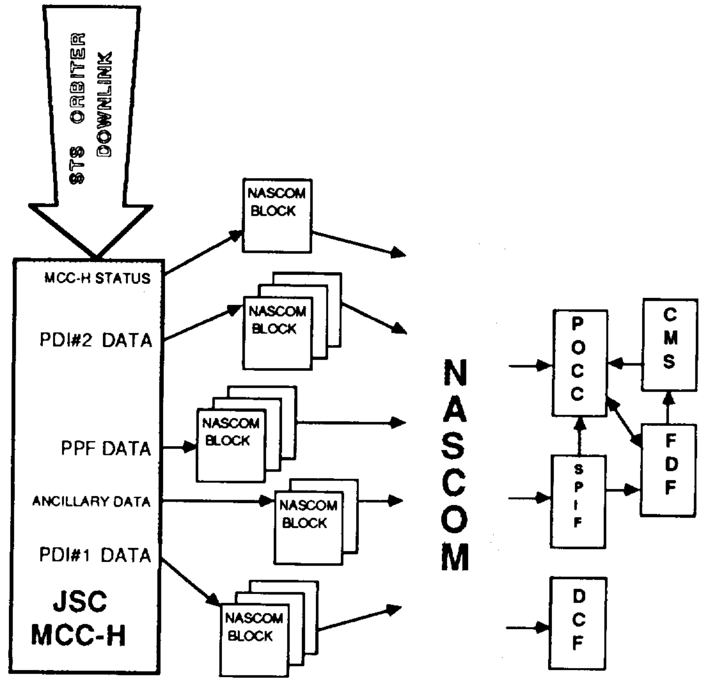


Figure 5-6. UARS Mission Timeline for Launch and Deployment

addition, the SPIF will separate specific portions of data (including STS orbit, attitude, RMS joint angles, and sun angles) from the STS orbiter data block and will send that data to the FDF.



PDI#1 - 32 kbps hardline telemetry

PDI#2 - 1 kbps hardline or RF telemetry

PPF - Payload Parameter Format (UASE Data)

Ancillary Data - Selected STS TLM Parameters

Figure 5-7. Ground System Functions and Interfaces During Launch and Deployment

The Flight Dynamics Facility (FDF) will receive the STS orbit, RMS, and other orbiter data from the SPIF, will calculate ephemeris coefficients for the UARS Onboard Computer (OBC), and will transmit these coefficients to the Command Management System (CMS). In addition, the FDF will process spacecraft attitude and position data into real-time video displays at the POCC.

The Command Management System (CMS) will convert the calculated ephemeris coefficients from the FDF to an uplinkable UARS ephemeris table load.

Launch and deployment operations will demand a high degree of coordination and communication. They will require special interfaces between the MCC-H, SPIF, and FDF in order to process the data flowing to and from the STS. Normal flight operations (when the UARS is on-orbit) will not have to interface with the MCC-H to send commands, nor will the downlink have to be processed by the SPIF and by the special STS-related software in the FDF. Figure 5-8 shows the ground system elements for Launch and Deployment.

5.5.1.2 STS Launch

The STS Launch phase begins with the launch of the STS from the Kennedy Space Center (KSC) and ends when the orbiter establishes the deployment orbit for UARS. During this phase, there will be no UARS flight operation activities.

5.5.1.3 Post-insertion

The Post-insertion phase begins when the UARS is configured to remain in the STS cargo bay for an extended period of time. The MCC-H will direct the STS crew, through voice communication, to place the orbiter in a safe operational condition. This includes opening the payload bay doors to dissipate thermal energy, establishing orbiter-to-ground communications, and inhibiting orbiter operations that might damage the UARS while the payload bay doors are open.

An astronaut on board the orbiter will initialize the UARS Airborne Support Equipment under the direction of the MCC-H. Once the UASE is on, the FOT will remotely check the UASE at the POCC using UASE video displays provided by the SPIF will

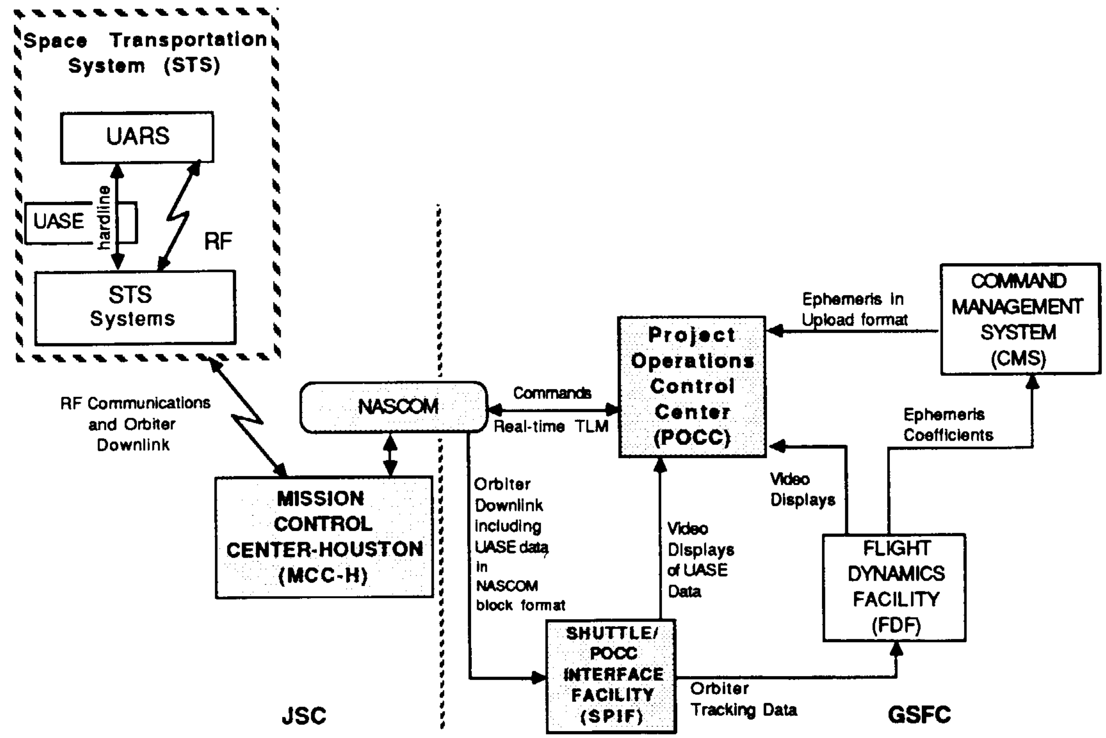


Figure 5-8. Ground System Configuration During Launch and Deployment

verify proper interface with the STS communication systems. During UARS initialization, the FOT will command the UARS survival heaters to establish UARS temperature control. In addition, the FOT will send the command to begin battery charging.

5.5.1.4 Payload In-Bay Checkout

The Payload In-Bay Checkout is an extensive testing procedure designed to assure that the UARS subsystems are functioning properly. Payload In-Bay Checkout will begin after the initialization procedures have been performed during the Post-insertion phase. This phase will include a Multimission Modular Spacecraft (MMS) functional checkout to assure the performance of the Modular Attitude Control Subsystem (MACS), Control and Data Handling Subsystem (C&DH), Signal Conditioning and Control Unit Subsystem (SC&CU), and Modular Power Subsystem (MPS).

All MMS prime and redundant subsystem components will be powered on to verify electrical continuity and telemetry. In addition, Subsystem Confidence Testing will verify the proper operation of specific UARS subsystems that are not part of the MMS. All prime and redundant components will be checked as in the MMS testing procedure. An ephemeris uplink will be completed to load the OBC with the data required for attitude control, attitude determination, and pointing.

5.5.1.5 Deployment

The Deployment phase includes both STS orbiter and POCC operational activities. First, the STS will be prepared for deployment of the UARS. The MCC-H will direct the STS to maneuver to a deployment attitude such that the sun will not damage any of the UARS instruments. After the STS is ready for the RMS operations, the UARS will be prepared for deployment. Preparation will consist mainly of disengagement of the UARS systems (hardline power, telemetry, command functions) from the STS. Once the UARS is electrically disconnected from the STS, telemetry from the UARS will be suspended until an RF link is established between UARS and the POCC.

The RMS deployment procedure will be initiated by unberthing the UARS from the STS payload bay. The UARS observatory will then be rotated and translated on the end of the RMS to an orbital attitude suitable for continued checkout and testing. When the UARS observatory is placed in the appropriate checkout orientation, it will communicate with the ground though the STS RF system, using an RF link between the UARS Omni-antenna and the STS. Once this link is verified to be operating properly, the High-Gain Antenna System will be tested, and a command-and-telemetry link will be established between the High-Gain Antenna and the Tracking and Data Relay Satellite (TDRS). At this point, communications will be available both through STS RF systems and through the Space Network.

The solar array will be deployed and checked next, to assure UARS power. This will be followed by deployment and testing of the Solar Stellar Pointing Platform (SSPP) and the PEM ZEPS instrument boom. After these have been tested by POCC commands, the grapple fixture on the UARS will be released by the RMS at the direction of the MCC-H.

5.5.1.6 Post-release

The Post-release phase is the final operation to be performed in conjunction with the STS orbiter crew. Separation from the STS will be completed by releasing the UARS spacecraft and pulling the RMS back to a safe position. At this point, the FOT will send a command to activate the UARS attitude control reaction wheels. The STS crew will then perform an STS Backoff Maneuver, moving the STS away from the UARS to a distance of at least 48 feet. Next, the POCC will send a command to the UARS to enable the use of UARS thrusters to achieve attitude stability.

At the end of UARS separation, the FOT will issue a command to reconfigure the Omni-antennas for communication through the Space Network. This will discontinue communications through the STS orbiter, and leave communications through the High-Gain Antenna and the Space Network as the the primary link between UARS and POCC. Final Checkout of the UARS will be completed entirely by POCC commands. Any subsystem which was not checked while in the STS orbiter bay or on the STS RMS will be tested at this time.

5.5.2 Early Orbit Operations

5.5.2.1 Activation

An activation period of approximately thirty days is planned to permit turn-on and initial checkout of various spacecraft and instrument systems. Throughout this period, spacecraft and instrument operations will be planned and controlled from the POCC. Each instrument investigator will be scheduled to support the activation of his instrument from GSFC.

During the instrument activation period each instrument will be gradually brought up to full operation. Most of the instruments will have outgassing periods of 14 days or more before they are activated. Some will require heaters and other equipment to be placed in a specific configuration before the outgassing period. Some instruments will unlock the gimbals of their rotating structure so they can be placed in an orientation compatible with thermal and activation constraints.

Each instrument investigator will activate his instrument ar bring it up to nominal operating condition. The activation of eac instrument will be scheduled for a designated time at the end c the outgas period, and will be scheduled around routine space craft operations. Most of the activation procedure will be conducted by means of stored commands, but each instrument team will be at the POCC during scheduled contacts to conduct real-time command and telemetry verification.

Each instrument team will devote as much time as possible to activating and checking out its particular instrument. Instruments already activated at any given time will be operated by means of routine stored command loads. Additional activation time may be scheduled for instrument teams if required for dealing with anomalous conditions. Instrument teams will have to rely on data from their RACs to assess performance of their instruments; no Instrument Ground Support Equipment (IGSE) will be present at the POCC.

As each subsystem or instrument is activated, routine operations for that subsystem or instrument will begin. In early stages of routine operation, various instrument investigators may be asked to perform Mission Planning Group functions either at GSFC or through the CMS-RAC interface. This involvement of the instrument investigators may be required to establish an initial performance baseline and to confirm or update predefined operating sequences.

Once the performance baseline and operating sequences are established, planning responsibilities for routine operations will move to the Mission Planning Group. The Project Scientist will coordinate with each instrument investigator to schedule this transfer of responsibilities. By approximately sixty days after launch, all planning responsibilities for routine instrument operations should rest with the Mission Planning Group. In case of unexpected instrument performance, the Project Scientist may extend or reinstate investigator responsibility for mission planning functions.

The activation period will include a number of activities to prepare the spacecraft for routine operation. A stored command routine will be established by loading a stored command block once per day at a specific time of day, and a contact and tape recorder management routine will be established with these stored commands. The tape recorders will switch back and forth between playback and record, to ensure that all data are captured.

Spacecraft ephemeris management will begin, loading a new ephemeris into the OBC each day or as required by the ACS software to maintain observatory pointing. Early in the activation period, the ACS will be commanded to use star tracker information, and fine pointing with errors of less than 108 arcsec will be established.

5.5.2.2 Alignment

Some of the spacecraft subsystems and some of the instruments will require alignment and calibration. This will confirm or improve upon pre-launch knowledge of various performance parameters relating to pointing and positioning of the spacecraft and instruments. The program of calibration and alignment will begin once routine operations have been established for the spacecraft and all instruments.

Some of the spacecraft subsystems that may require alignments and calibration are: the Fixed-Head Star Tracker (correctly determine its orientation with respect to the other FHST and ACS master reference point), Earth Sensors (correctly align their positions and calibrate them for correct pointing), Fine Sun Sensor (correctly align its position and calibrate it for correct pointing), gyros (calibrate the drift of all 3 gyros), HGAS (calibrate for pointing and gimbal angles), SSPP (calibrate pointing), and the solar array (calibrate the tracking function). Once these spacecraft alignments are completed, the instrument boresight alignment analysis can proceed. This will determine and correct for any misalignment or calibration shift incurred during launch or early orbits.

As telemetry data are accumulated, the Flight Dynamics Facility (FDF) will analyze spacecraft attitude sensor data to develop post-launch calibration and alignment parameters for each sensor. Instrument investigators will also analyze instrument measurements to develop boresight orientation data. This data will be used by the FDF to develop comparable post-launch alignment values for specific participating instruments and for the basic spacecraft alignment reference system.

If spacecraft maneuvers (5-degree calibration roll, yaw reversal) are required to provide analysis input data, the FDF will define appropriate maneuver requirements for implementation by the Mission Planning Group and Flight Operations Team. Instrument investigators will help define the maneuvers that involve instrument data acquisition. Based on these analyses, it may be necessary to provide updates to calibration and alignment parameters stored in the On-Board Computer. If such updates are required, the FDF will provide update information to the Flight Operations Team for implementation. The Flight Operations Team will then convert this information into OBC table loads using the POCC computer system. The Software Development and Verification Facility (SDVF) will provide support as needed.

5.5.3 Spacecraft Maneuvers

Special spacecraft maneuvers will be scheduled from time to time throughout the UARS mission. These will include yaw turnaround maneuvers to accommodate sun/orbit plane transitions, roll offset maneuvers to permit above-limb viewing by selected instruments, special attitude offset maneuvers to provide sensor calibration data, and orbit adjust maneuvers to compensate for gradual decay of the observatory orbit. Advance notice of each maneuver will be given in sufficient time to be factored into the normal daily planning cycle, which normally begins four to seven days before the operational day.

A nominal plan for each type of maneuver will be available prior to launch, and will serve as the starting point for planning each maneuver. The definitive plan for each maneuver will be developed jointly by the Flight Operations Team and the Flight Dynamics Facility. This will be available for review and comment at least four days before the day of the maneuver.

5.5.3.1 Yaw-around

A yaw-around maneuver will be required approximately every 34 days. The schedule for these maneuvers will be dictated by the sun angle and the restriction that sunlight not be on the cold side of the spacecraft at an angle of greater than 10 degrees. This restriction provides 1 or 2 days latitude around the sun crossing time to perform the yaw-around maneuver. The sun crossing time is that point at which the sun crosses the spacecraft orbit plane.

This 180-degree yaw slew will be accomplished during a 45-minute period centered about midnight of the umbra. Pre- and post-maneuver operations will extend the maneuver time to a total of 8 hours. The entire operation will be under control of the POCC, but the spacecraft has the capability to complete the maneuver or return to the original position if contact with the POCC is lost. The 180-degree yaw slew will be accomplished with reaction wheels only. During the maneuver, the direction of solar array rotation must be reversed for the solar array to continue tracking the sun. The instruments will be placed in a standby condition prior to the maneuver and will remain at standby until the maneuver is completed.

5.5.3.2 Alignment Roll Offset

A roll offset maneuver may be required for calibration and alignment of instruments. This consists of a roll up of the cold side of the spacecraft by approximately 5 degrees to provide certain instruments a view above the horizon. The view will provide star and planet contacts, and a view of space for calibration. Of the instruments not requiring this maneuver, some will be placed in standby, while those instruments with their own pointing systems will continue to operate. The roll up will be maintained for a short period, after which the observatory will return to nominal position.

Those instrument investigators whose instruments are involved in roll offset maneuvers will also participate in planning the maneuver sequence. Any instrument reconfiguration that needs to take place before or after any maneuver will be planned by the instrument investigator and will be coordinated and scheduled by the Mission Planning Group.

5.5.3.3 Orbit Adjust

Orbit adjust maneuvers will be performed periodically to keep the observatory close to the nominal 600 km altitude orbit. The schedule for these maneuvers will be dictated by orbit decay and by orientation of the observatory. Due to the yaw-around maneuvers, the observatory is only in proper position to add velocity, and thereby increase the orbit altitude, about half of the time.

The Flight Dynamics Facility will provide the necessary parameters for the orbit adjust maneuver. The FDF will also perform near real-time attitude determination throughout each maneuver. Normal observatory operations will be suspended during a period of time around the maneuver to allow preparation for and recovery from the event. The Flight Dynamics Facility will generate appropriate ephemerides and planning aid updates as soon as possible after the orbit adjust maneuver is completed.

5.5.4 Contingencies

During the UARS mission, various anomalous events could require the operation of the observatory in other than the normal mode. These situations will be covered by contingency plans and procedures. Some of the contingency situations that will be planned for are: loss of communications, loss of attitude control (the inability to maintain precision pointing), and loss of power or reduced power capacity. In contingency situations, normal operational support will be augmented or modified to suit specific needs.

Contingency plans involving loss of communication would be triggered by the absence of telemetry from the observatory during a scheduled contact or by the inability of the observatory to respond to commands. This would occur if the observatory's High-Gain Antenna System (HGAS) failed to point to TDRS, or if the onboard transmitter were not turned ON, or if the onboard transmitter were not properly configured due to failure of stored command processing. Communication contingencies could also arise from loss of the Space Network.

In the absence of Space Network support, the Deep Space Network (DSN) resources can be scheduled to provide emergency communication with the UARS Observatory. The DSN can provide access to the observatory during approximately 13 of 15 orbits per day. However, because of orbit geometry and DSN station location, there may be intervals of up to four hours with no coverage. Should the need for DSN support arise, the Flight Operations Team will notify the NASCOM Control Center (NCC) that a spacecraft emergency exists and that DSN support is requested. The FOT will notify the NCC through the MSOCC Scheduling Office.

In the event of a loss of communications, contingency operations will use the spacecraft Omni-antenna to establish command and telemetry either through an alternate TDRS link or through a DSN link. Once communications are established, the possible cause of the problem can be determined, and the POCC can issue a command for proper configuration or a reconfiguration using redundant components.

The spacecraft contains software and hardware that can detect certain situations where operations are outside of nominal preset conditions. Such out-of-bound conditions could be caused by a component failure or by improper commanding. Should the spacecraft detect such conditions, it will switch into a mode known as SAFEHOLD, to protect the observatory until contact is established and the problem is corrected.

SAFEHOLD mode involves non-precision attitude control operation in a nominal spacecraft orientation, and may also involve interruption of stored command execution. Should a SAFEHOLD condition be encountered, the Flight Operations Team will immediately confirm that no spacecraft subsystem or instrument has been left in a dangerous configuration, and the FOT will take prescribed corrective action if required. Attention will then be directed toward determining the cause for transferring into SAFEHOLD and toward planning and implementing a corrective action and recovery procedure.

Flight Dynamics Facility support for near real-time attitude determination and troubleshooting assistance will be requested as soon as possible after the SAFEHOLD condition is detected. Such support will continue until recovery operations have been completed. Full recovery from a SAFEHOLD condition is expected to occupy the operational ground system for six to eight hours plus whatever time is needed to isolate and understand the cause.

For situations that involve spacecraft computer operation, the Software Development and Validation Facility (SDVF) may become involved. Computer memory-dump data will be transmitted from the POCC to the SDVF for examination. If a non-permanent table parameter change becomes necessary, the POCC will generate an appropriate corrective table update; if a permanent table parameter or coding change is required, the SDVF will generate and transmit the corrected memory image to the POCC. The POCC will convert this input into uplink load format and will transmit it to the spacecraft. A subsequent memory dump of the affected memory area will be obtained by the POCC to verify that the load operation was successful.

In the event of an instrument health/safety incident, the Flight Operations Team will follow instructions prescribed by the instrument investigator and will notify him of the occurrence as soon as possible. When possible, access to pertinent telemetry data will be arranged by the FOT Instrument Engineer if requested by the Investigator. The instrument investigator will be responsible for evaluating the incident and for advising the Mission Planning Group of instrument status and plans for resuming operation.

5.6 Prelaunch Readiness

Prelaunch readiness activities include all those tasks that prepare the UARS ground system equipment and personnel to support the spacecraft during the UARS mission. This process requires numerous hours of development, planning, training, analysis, and coordination among all of the flight operations personnel, including those in the Flight Operations Team (FOT), the Mission Planning Group (MPG), the Mission Operations and Data Systems Directorate (MO&DSD), Kennedy Space Center (KSC), Johnson Space Center (JSC), and at the observatory contractor.

As a first step, the ground system configurations must be developed and implemented. Development includes the acquisition of new hardware and software as well as the integration of new elements with existing facilities. Once the ground systems are operational in the UARS configurations, tests and simulations will be used to train personnel and to validate the equipment, software systems, databases, and networks. Finally, the actual UARS hardware will be introduced in the validation activities, first during subcontractor tests and then at KSC with prelaunch tests involving all of the NASA centers (GSFC, JSC, KSC), subcontractors, and flight operations teams.

SECTION 6
GROUND DATA HANDLING SYSTEM

Section	Page

6. Ground Data Handling System

6.1 Mission Baseline

The following UARS mission baseline elements relate to scientific data processing. Figure 6-1 shows the UARS Ground Data Handling System (also see Figure 5-1).

6.1.1 Period of Data Operations

Data processing and analysis will begin at launch and will continue for at least 1 year after the termination of satellite operations. Data will be available through the National Space Science Data Center (NSSDC) two years after the data is transmitted to the ground.

6.1.2 UARS Investigator Complement

Each of the Instrument Principal Investigators and their associated Co-Investigators (Co-Is) has a UARS instrument. There are 10 other PIs with their Co-Is who will conduct theoretical studies. In addition, two collaborative investigators are developing research algorithms to aid in processing data from two of the remote sensors. The theoretical and instrument PIs, and the collaborative investigators form the UARS Science Team. The Science Team is chaired by the Project Scientist.

6.1.3 Data Processing and Analysis Facility Support for Investigators

All members of the Science Team will have facilities for the analysis of UARS data. These will consist of Remote Analysis Computers (RACs) connected to a Central Data Handling Facility

(CDHF). The CDHF will be the source of processed UARS data that can be accessed by any RAC. The instrument investigators will write programs that the CDHF will use to process the UARS raw data into a form suitable for scientific analysis. Each Principal Investigator (PI) from the United States will receive either a dedicated RAC or the shared use of a RAC. There are two PIs at the Jet Propulsion Laboratory (JPL), two at the Langley Research Center, and two at the University of Colorado. Each of these sites will have one RAC for shared use. Another RAC will be furnished to the Co-Is for the Particle Environment Monitor (PEM) instrument at Lockheed, Palo Alto Research Laboratory.

Most RACs will have a dedicated communications link. The exceptions are the ISAMS team and Dr. White, who will share a communications link to England, and the CLAES team and PEM Co-Is, who will share a communications link to Lockheed at Palo Alto, California. RACs that will be used for developing production software will be connected to the CDHF in early 1987. The remaining RACs will be connected to the CDHF approximately 18 months before launch.

6.1.4 Synchronization of Instrument Operations with Telemetry

Each instrument will receive a pulse coincident with the beginning of an Engineering Minor Frame (EMIF) and a pulse coincident with the beginning of an Engineering Major Frame (EMAF). Where feasible, each instrument will synchronize the control and readout of data to these pulses so that: 1) The beginning of an EMAF will coincide with the beginning of a measurement cycle and 2) There will be an integral number of measurement cycles per EMAF.

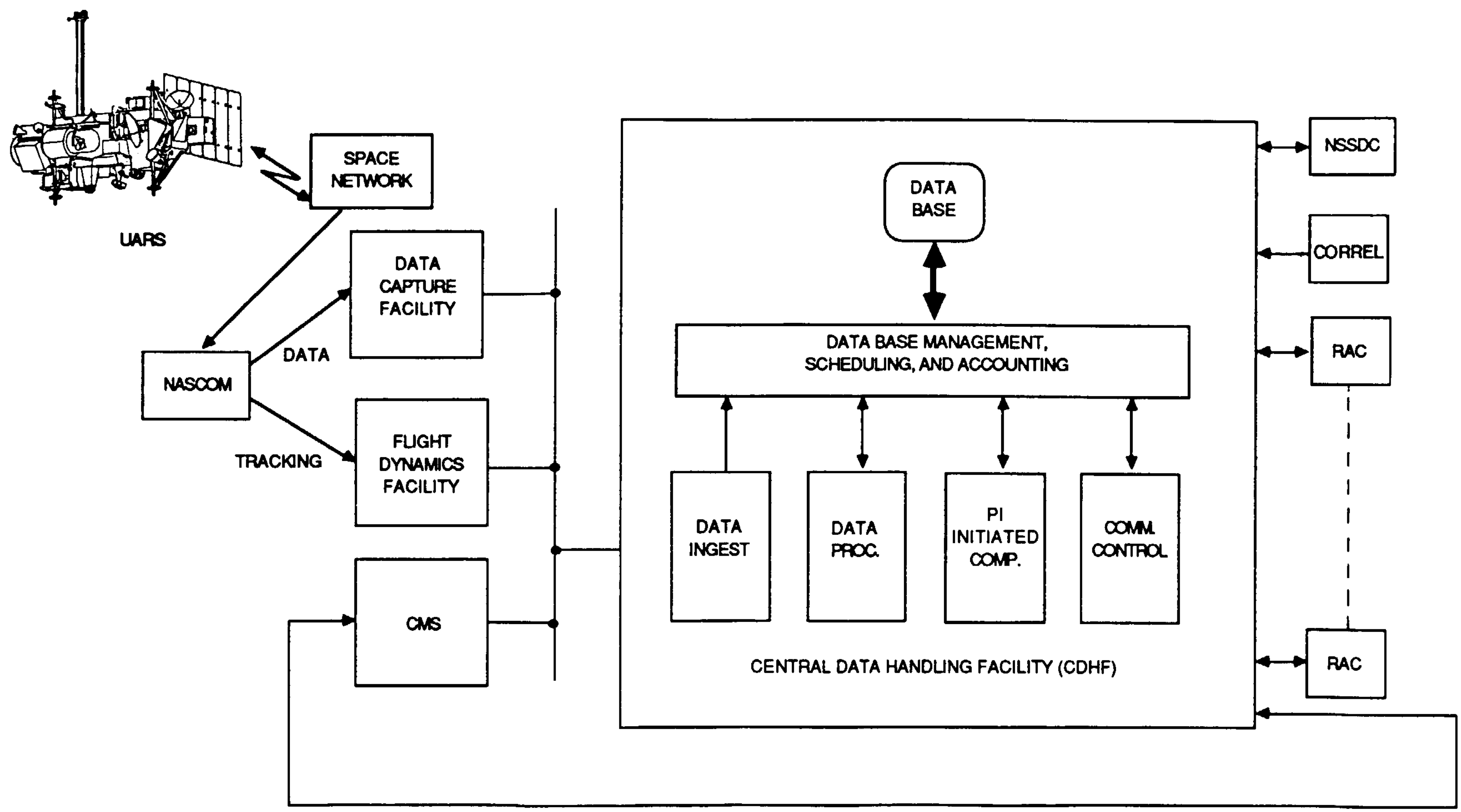


Figure 6-1. UARS Ground Data Handling System

6.1.5 Time Codes

There will be two time codes included in telemetry. One counter serves as both a minor frame counter and a relative time clock. This will not be reset. There is also an absolute time clock included in OBC data in telemetry. This has an error of less than 10 milliseconds from universal time (UT).

6.1.6 Telemetry Readout

The 32 kbps science data will be continuously recorded onboard the spacecraft. Each of the two observatory tape recorders can store two orbits of 32 kbps data. A tape recorder will be played back in reverse direction at 512 kbps through the Space Network's Tracking and Data Relay Satellite (TDRS). Playback will nominally be once per orbit. Real-time data at 32 kbps will also be transmitted during the TDRS contacts. Both the playback and the real-time data will use S-band single access channels, and both will be forwarded as they are received from White Sands to Goddard. The NASA Ground Terminal (NGT) at White Sands will provide for data protection in the form of storage and replay in case of line outage.

The transmission of real-time and playback data at 32 kbps and 512 kbps requires the pointing of a high-gain antenna on UARS toward the appropriate TDRS. If a problem should temporarily prevent the accurate pointing of the TDRS antenna, the telemetry system will be commanded to transmit the 1 kbps engineering data. These data would be transmitted through an omnidirectional antenna system, again using TDRS services, to the Project Operations Control Center (POCC).

6.1.7 Scientific Data Capture

Scientific data from tape recorder playbacks will be captured and preprocessed at GSFC at an institutional data capture facility (DCF). If one of the two flight tape recorders should fail, the DCF will receive, capture, and merge the real-time data with the playback data. Should both flight recorders fail, the DCF will receive only the real-time data. In that event, contact time would be limited only by the availability of the Space Network to provide link support. The preprocessed data will be transmitted from the DCF to the UARS CDHF at GSFC for processing.

6.1.8 Instrument Status Identification

The current status of each instrument will be telemetered to the ground so that data processing may proceed without a knowledge of instrument command history.

6.1.9 Availability of Correlative Data

The US National Meteorological Center and the British Meteorological Center will supply daily sets of atmospheric data from in-situ and satellite measurements. The National Oceanic and Atmospheric Administration (NOAA) will supply data from the Solar Backscattered Ultraviolet Spectral Radiometer (SBUV) instrument flown on another spacecraft. Other correlative data sources are one-time measurements from various sources such as balloon, rocket, and shuttle flights.

6.2 Data Processing System Elements

Playback data from the observatory are relayed through TDRS to the NGT at White Sands. Tracking data and the playback data are forwarded from White Sands to Goddard using NASA Communications (NASCOM) circuits. The tracking data are received by the FDF where predicted and definitive orbit calculations are made. The definitive orbit results are forwarded electronically by the Flight Dynamics Facility to the CDHF.

Playback data from White Sands are captured in the DCF located at GSFC. The DCF archives the raw data, performs space and ground link quality checks, reverses the data to time-increasing order, removes redundant data, and decommutates and formats the data for transmission to the CDHF.

The FDF, DCF, and CDHF exchange data through a local area network. The RACs communicate with the CMS through the communications controller in the CDHF. The communications controller provides a gateway to the CMS, and it lets the PIs communicate with the CMS using network protocol and data formats unique to the RAC manufacturer, DIGITAL.

The CDHF will perform the following functions:

Scientific data, engineering and spacecraft data, OBC data, definitive attitude, solar and lunar ephemerides, predicted and definitive orbit, and correlative data will be ingested, cataloged, and stored.

The scientific data will then be processed to a form suitable for scientific analysis using programs supplied by the PIs. The processed data will also be cataloged and stored.

A computational capability for use by the investigators will be accommodated in the CDHF.

Data base management software and various utility routines will be available in the CDHF.

6.3 Requirements

6.3.1 General

The UARS ground data processing system will provide the timely delivery of data products suitable for scientific analysis. It will also satisfy the following objectives:

> All meaningful instrument data will be processed through Level 3A using software developed and validated by instrument investigators.
>
> All Level 3A data will be processed to Level 3B.
>
> All of the processed data will be available to the UARS Science Team.

Following an algorithm validation period, the production processing of instrument data to Level 3A by the CDHF will occur as soon as feasible. Operational scenarios have not been developed but a maximum time limit of 17 days has been set for production processing of data following its transmission to the ground. It is expected that the actual processing delay will be less than 17 days.

Mapped, geophysical parameters, the final product of data processing, will be maintained in on-line storage for the planned life of the mission. Investigators will interact with this central facility using RACs. The primary criterion for the division of labor between the RACs and the CDHF is that routine processing and storage of data will occur in the CDHF, while the analysis of data requiring human interpretation will occur at the RACs, following the transfer of selected data to the RACs. The RACs will also be used to develop the data processing software used in the CDHF.

6.3.1.1 CDHF Software System/Production Program Interface

A UARS CDHF Software System (UCSS) will be developed for use by the investigators in developing their data processing (DP) programs. The UCSS will contain Fortran-callable routines to open and close files, read orbit and attitude data, read and write levels 0 and 3A data, catalog data files, initialize and terminate the execution of DP programs, and perform various other utility functions.

6.3.1.2 CDHF User Interface

A tree-structured "help" file will supply information for using the CDHF system. The help file will include information regarding the use of the data catalog, descriptions of data read/write routines, methods available for data transfer, descriptions of orbit/attitude read/write routines, and so forth.

6.3.2 Data Definitions

6.3.2.1 Data Levels

Data from UARS instruments will undergo several processing steps starting at Level 0 and progressing to Level 3. Data produced by Level N processing will be referred to as Level N data.

Level 0 data are raw telemetry data in which the data reversal, quality check, editing, and decommutation functions have been performed. As Level 0 data are created, data quality information will be handled in two ways. A binary indication of data quality for each Science Major Frame (SMAF) (or 1.024 seconds) will be included with the Level 0 data. Also, a binary indication of data quality for each Science Minor Frame (SMIF) (or 32 milliseconds) will be held in a separate quality data file.

Level 0 data are processed in steps to Levels 1, 2, and 3. Some parts of the Level 0 data sets are not appropriate for further processing. For example, only data collected during sunrise or sunset from the HALOE instrument will be processed into higher level data products.

For those instruments that remotely sense the atmosphere, Level 1 data represent measurements of radiance at particular instrument settings of field-of-view, sample time, and filter value. Level 2 data are the geophysical parameters of temperature, winds, or gas concentrations that are derived from the radiance measurements. Level 2 data are still generally located in time and space commensurate with instrument pointing and sampling. Level 3A data are gridded Level 2 data of vertical profiles on 65.536 second centers. The Science Team will approve a spatial grid for creating Level 3B data from the Level 3A data. The gridding PI will develop and validate the Level 3B gridding programs.

The definitions for Levels 1, 2, and 3 data vary somewhat from the above definition for the instrument measuring the particle environment (PEM), and for the two instruments measuring the solar energy input to the atmosphere (SOLSTICE and SUSIM) since data from those instruments are not represented in an atmospheric grid.

6.3.2.2 Time Codes

The UARS has a relative time code and an absolute time code included in telemetry.

Relative Time Code

Included in UARS engineering data is a 24-bit binary counter that increments by 1 count each EMIF. The least significant 6 bits of the counter are an EMIF counter. These are all zeros for the first EMIF of an EMAF. The entire 24-bit counter has a resolution of 1.024 seconds and a range of more than 198 days. It can be used for time correlation and data accounting.

Absolute Time Code

The OBC computes and telemeters an absolute time code to the ground in OBC data. Once each reporting period, the OBC will add a time increment to the time code. The POCC will monitor any drift in the clock and change the value of the increment as necessary to maintain an absolute error of less than 10 milliseconds between the transmitted time code and UT, formerly called Greenwich Mean Time (GMT). The time code will have two integer fields: millisecond and epoch year. The millisecond field contains the number of milliseconds since the beginning of the epoch year. Leap seconds will be added to the time code when they occur.

6.3.2.3 Data Formats

Level 0 Data

Each logical Level 0 record will span one EMAF and have time, data, and quality information. The time data will have the 3-byte relative time code and the 8-byte absolute time code. The data field will have either engineering data, OBC data, spacecraft data, or the data from one instrument for the 2048 SMIFs in an EMAF.

The quality information will consist of two 8-byte groups: one for parity information and one for zero-full information. The 64 parity bits correspond to the 64 SMAFs contained in the logical record. A "0" indicates that no SMIFs in the corresponding

SMAF had a parity error. A "1" indicates that at least one SMIF had a parity error. A parity error means that the 2-byte cyclic redundancy code contained in a SMIF does not agree with a value computed on the ground from the SMIF data.

The 64 zero-fill bits also correspond to the 64 SMAFs contained in the logical record. Here, a "0" indicates a complete logical data record. A "1" indicates that at least one SMIF in the corresponding SMAF had missing data that was filled in with zeros.

Quality Data

In addition to the ten instrument data sets, OBC data, and engineering and spacecraft data, the DCF will send a file of quality data to the CDHF. The quality data file will contain time and quality information. A logical record will span one EMAF.

The time data will have the 3-byte relative time code and the 8-byte absolute time code. The quality data will consist of 2048 bits (256 bytes) of parity error data and 2048 bits (256 bytes) of zero-fill data. In each case, there is a one-to-one correspondence between the 2048 bits and the 2048 SMIFs in an EMAF. For the parity error data, a "0" means no parity error and a "1" means parity error in the SMIF corresponding to the parity bit. Similarly, for zero fill data, a "0" means no data gap. A "1" indicates that the SMIF corresponding to the zero-fill bit was not received completely and has been filled out with zeros. If there is a parity error for a SMIF, there is no way to determine which data in the SMIF are bad.

Levels 1 and 2 Data

The format of Levels 1 and 2 data will be determined by the instrument investigators whose software is used to produce the data. Investigators will document detailed data formats and data peculiarities in a machine-readable form to aid other users of the data. Any use of Level 1 or 2 data, however, should be coordinated with the appropriate instrument investigator.

Level 3 Data

Fortran-callable routines will be available to read or write level 3A data. Similarly, Fortran-callable routines will be developed to read level 3B data.

Level 4 Data

Level 4 data consists of higher level analysis products using processed data. The definition of the formats for Level 4 data are the responsibility of the investigator producing the data. For data of general interest, read routines developed by the PI, as well as detailed data formats and data descriptions, will be included with the data in a machine readable form. Use of the data should be coordinated with the responsible investigator.

Attitude and Orbit Data

Attitude and orbit data will be available through Fortran callable routines.

Correlative Data

A UARS PI will be responsible for each correlative data set maintained in the CDHF data base. Each PI will provide data description, formats, and Fortran-callable read routines to aid in the use of the particular correlative data set.

File Size

The time span for files for attitude, engineering, orbit, OBC, and levels 0 and 3A data, is one day, starting at 0 hours, universal time (UT). Level 3B files will also contain one day of data. Where feasible, levels 1 and 2 data files should similarly span one day, starting at 0, to maximize ease of use and facilitate data comparison.

6.3.3 DCF Requirements

6.3.3.1 DCF Input Data

During TDRS contacts, one of the two flight tape recorders will be played back at 512 kbps and real-time data will be transmitted at 32 kbps. The data will be forwarded by NASCOM from the NASA ground terminal at White Sands to GSFC. The DCF will capture and record the tape recorder playback data in the 512 kbps channel. In case one of the two flight tape recorders fails, the DCF will receive and capture both the 32 kbps real-time data and the 512 kbps playback data to provide continuous data coverage.

6.3.3.2 DCF Processing and Output Data

DCF data processing will include the following:

1. Calculations of Space Network block parity errors and requests for retransmission of data from the NGT at White Sands in case of line failure,

2. Reversal of tape recorder playback data to time-increasing order,

3. Elimination of redundant data produced when both flight recorders are recording,

4. Calculation of the Cyclical Redundancy Code (CRC) error-checking information included in each SMIF,

5. Editing of telemetry data into UARS EMAF,

6. Creation and accounting of zero-fill data as required to fill out missing data within one EMAF, and

7. Decommutation of the UARS science telemetry format.

The UARS science telemetry format will be decommutated by the DCF into 15 data files. There will be one file for each of the ten instruments, except for the SUSIM instrument. For SUSIM, there will be two files, SUSIMA and SUSIMB, corresponding to the two data systems in that instrument. There will also be one file of OBC data, one of engineering data, one of spacecraft data, and one file that indicates quality information at the SMIF level. Summary quality information at the SMAF level is included in each of these files.

The blocking of data within each data set will correspond to one EMAF. The position of each SMIF and SMAF within an EMAF record will be based on the SMIF counters and relative time codes.

In addition to normal science telemetry processing, the DCF will perform quick-look processing of one playback per 8-hour shift. The DCF will schedule which playback to use for quick-look processing. The quick-look data will be forwarded to the CDHF within 1 hour of receipt by the DCF. The quick-look data processing will include the following:

1. Reversal of tape recorder playback data to time-increasing order,

2. Calculation of the CRC error-checking information included in each SMIF,

3. Editing of telemetry data into UARS EMAF,

4. Creation of zero-fill data as required to fill out missing data within one EMAF, and

5. Decommutation of the UARS science telemetry format.

The raw telemetry will be recorded at the DCF and archived for one year. The most recent 7 days of playback data will be kept locally in the DCF and will be made available to the POCC within 1 hour of a requested playback. Older data will be archived off-line and a playback requested by the POCC will be available within 1 day of the request.

During data receipt, the DCF will provide link quality status of the tape recorder playback data to the POCC.

6.3.4 CDHF Requirements

6.3.4.1 CDHF Input Data

Scientific Data

The CDHF will receive a daily input of raw telemetry data from the DCF for processing, storage, and analysis. Data will also be received from the SBUV instrument on other missions. The frequency of input for SBUV data has not been determined but it is on the order of once per week.

Quick-Look Data

For each 8-hour shift, the CDHF will receive, by electronic link, one tape recorder playback that has been preprocessed by the DCF. This quick-look data will nominally have about one orbit's worth of data. The DCF will notify the CDHF 1 day in advance as to which playbacks are scheduled by the DCF for transmission to the CDHF as quick-look data.

Definitive Attitude

The CDHF will receive daily inputs of satellite definitive attitude data by an electronic link from the Flight Dynamics Facility (FDF).

Solar and Lunar Ephemerides

The means and frequency of receiving these data are to be determined, as are their volume.

Correlative Data

Correlative data will consist of data from sources such as balloon, rocket, and shuttle flights in addition to the input of daily measurements from the National Meteorological Center (NMC), and the possible input of satellite data from the British Meteorological Office. Correlative data will presumably be received by two methods. The data could be available at a RAC and be input to the CDHF using the RAC/CDHF communications link. Alternatively, a magnetic tape containing the data could be sent directly to the CDHF. Details of the correlative data are to be determined but it is estimated that the average volume of correlative data will not exceed 5 megabytes (MB) per day on a continuing basis, with varying inputs from aperiodic sources such as balloon flights. Correlative data will be used to validate and monitor data processing software, to perform specific scientific studies, and to provide temperature and pressure profile data for data processing programs.

Data Processing Programs and Tables

Data processing source code along with any necessary data tables will be generated at the RACs and sent to the CDHF as files.

UARS Ephemeris Data

The CDHF will receive daily inputs of both predicted and definitive satellite position data and velocity data by an electronic link.

Engineering, Spacecraft Housekeeping, and OBC Data

The CDHF will receive a set each of engineering, spacecraft housekeeping, and OBC data each day.

Real-time Data

A study is underway to determine the feasibility and need for receiving 32 kbps data from each TDRS contact in the CDHF for access by instrument investigators at their RACs.

6.3.4.2 CDHF Processing Requirements

Science Data Processing

All Level 0 data are to be processed to Levels 1, 2, and 3 using software supplied by the investigators. Nine months before launch, an operational version of the software will be used with test data so that CDHF operations personnel can become familiar with the programs.

During an algorithm validation period after launch, the CDHF operations crew will process a portion of the received data to develop CDHF operations with flight data. During this phase, at least 50 percent of the CDHF data processing resources will be available to investigators to aid in algorithm validation. This augments the computational resources allocated to investigators. After the algorithm validation period, the production processing of instrument data will be initiated by CDHF personnel. Algorithm validation will be on an individual instrument basis.

Following algorithm validation, the backlog of data since launch will be processed along with then currently received data. The system will be sized so that backlog data can be processed at least as quickly as current data. This means that a 1-month backlog should be worked off in 1 month or less. After algorithm validation, the production processing of data is the responsibility of CDHF operations personnel. The processing algorithms will contain some tests for data reasonableness.

Improvements in algorithms or corrections of software errors may lead to a reprocessing of data after production processing has begun. Any decision to reprocess data will be made by the Project Scientist on an individual instrument basis. Current plans assume that there will be a final, complete reprocessing of data before sending the Level 3 data to the National Space Science Data Center (NSSDC) which is located at Goddard Space Flight Center.

Quick-Look Data Processing

The CDHF will receive one flight recorder playback each 8-hour shift. The last three quick-look playbacks are to be held in disk storage where they can be accessed by the RACs. Earlier quick-look data sets will be erased. Raw, onboard estimates of attitude will be extracted from the data for quick-look analysis.

Attitude Data Processing

A file of attitude sensor data and OBC attitude computational results will be extracted from each OBC and engineering file received from DCF. The attitude sensor data will be sent to the FDF for processing into attitude results. Observatory attitude and SSPP attitude information will be extracted from OBC data and will be made available for use in the CDHF prior to the receipt of definitive observatory and SSPP attitude from the FDF.

Attitude interpolation routines and other utilities will be developed for general use.

Solar and Lunar Ephemeris Data Processing

The source of these data are to be determined. The data will be cataloged and stored upon receipt for access by science data processing programs.

Correlative Data Processing

In general, no processing of correlative data is planned other than having it cataloged and stored upon receipt for access by the Science Team.

Data Processing Programs and Tables

The PI developed data processing programs and associated data tables used for production processing will be cataloged and stored.

Orbit Data Processing

Definitive and predicted orbit data will be received, cataloged, and stored daily. Also, orbit interpolation routines will be developed for general use.

Engineering and Spacecraft Data Processing

Engineering data files and spacecraft data files will be cataloged and stored with no further processing.

Archival Requirements

All cataloged data will be held in the CDHF for the life of the mission on some form of machine-readable storage medium, e.g., optical disk or magnetic tape. Some examples of cataloged data files are:

- All Levels 0, 1, 2, and 3 data
- OBC, engineering, extracted attitude, and predicted orbit data
- Definitive orbit and attitude data
- Solar and lunar ephemerides
- Correlative data

- System software, including the data catalog
- Data processing programs and associated data tables

The following data types will be copied to either optical disk or magnetic tape and will be moved to safe storage within one week of their receipt in the CDHF: Level 0 data, attitude and orbit data, correlative data, system software, and data processing programs with their associated data tables.

Once a month, Level 3 data not already in safe storage will be copied to a magnetic tape or optical disk and moved to a safe storage area.

Data Management Requirements

Software will be developed to catalog the following data types: Levels 0, 1, 2, and 3 science data, attitude and orbit data, solar and lunar ephemerides, correlative data, and data processing programs with their associated data tables. The catalog will contain characteristics of the data sets — including description of data contents, time span, format, quality, time of creation, and program version used for processing. The catalog will be searchable on at least the following keys: time, instrument, data level, and measurement type. The results of a catalog search will indicate the file name of any data files meeting the search criteria.

Subroutines will be developed by the applications software system contractor to open and close a file, catalog a file, and read and write level 0 and level 3A data records. These subroutines will be available to all investigators and will use record and file management services supplied by the CDHF computer manufacturer and the RAC manufacturer. A user may remotely access any file for which he has "read privileges" by using services provided by the VMS operating system and by the DECnet communications system.

System Accounting Requirements

A log will be maintained of CDHF activity. The log is a management tool and is not intended to log all operator key-ins. The major reportable elements to be included are: RAC requests for major activities, a synopsis of data transfer requests, and the status of CDHF processing tasks.

ACRIM II Data Processing Requirements

Once a week, a magnetic tape will be mailed to the PI for the ACRIM II instrument. The tape will contain ACRIM II Level 0 data, the best available attitude and orbit data, and selected engineering data. These data sets will have the same time span. The data on each tape will include all data received since the last tape was mailed.

Investigator-Initiated Computations

A computational resource will be available in the CDHF for use by the investigators. This capability will be shared among the investigators. It is not intended to support the execution of large models or other large computational loads.

Observatory Status Log Processing

A status log will be generated which is a time-tagged list of significant observatory changes. The log will be produced from

OBC, engineering, and level 0 data. The time span of each log will be one day beginning at 0 hours, UT. Input data contained in SMAFs having either parity errors or fill data may be ignored. Typical changes and events to be logged are:

ACS pointing mode
- fine pointing (forwards/backwards)
- safehold
- roll maneuver (slew/point)
- yaw maneuver (slew/settle)

SSPP pointing mode
- slewing
- pointing (solar/stellar)

Data gaps
- loss of data for more than 10 minutes

Orbital events (sub-satellite point)
- equator crossings
- South Atlantic anomaly entry/exit
- light/dark terminator crossing

Instrument mode (up to 4 states per instrument, e.g., operate, calibrate, quiescent, off).

Attitude/Orbit Utility Processing

Utilities will be developed to provide, for a given time, satellite position and velocity; satellite attitude; limb tangency point given a view direction; position of sun, selected stars, and planets; and satellite orbital elements. Utilities will be developed to provide the Earth's radius given a latitude (using an ellipsoidal model), the start and stop times of a given orbit number, and the orbit number at any given time.

6.3.4.3 CDHF Output Requirements

The CDHF has two classes of output data: scheduled outputs and results available for output on demand. Data scheduled for output will be sent to the NSSDC. The data catalog and all levels 3A and 3B data, will be sent to the NSSDC after final processing. Levels 0 through 2 data will be sent to the NSSDC on request.

Demand-Access Data

Data products and reports may be accessed remotely by logging-on to the CDHF computer and copying a file to a RAC. The data catalog query capability will supply information about data files.

Data may be shared among users by RAC-to-RAC transfers or by placing data in a user's area in the CDHF and making the data available to others. This informal sharing of data is not controlled. The following data types are managed by CDHF system software and will be available for remote access from the CDHF upon request:

- Levels 0 and 3 data with read utilities
- Levels 1 and 2 data
- Correlative data
- Observatory and SSPP attitude with read utilities
- Observatory position with read utilities
- Solar, lunar, planetary, and selected star positions with read utilities
- Reports, including observatory status log, major activities log, and data processing status and schedule.

6.3.5 RAC Requirements

Each RAC must perform several functions.

The primary function is to access the data base in the CDHF to receive and store selected data sets for analysis. The data may then be used for scientific analysis at the RAC, or they may be input to a larger computer. This permits analyses beyond the capabilities of the RAC, such as the execution of global circulation models.

Investigators who collect correlative data can use the RACs for transferring those data to the CDHF for storage in the central data base.

Instrument investigators and collaborative investigators will use the RACs for the development of Levels 1, 2, and 3 processing software.

After launch, instrument investigators will use the RACs to validate their processing software prior to the start of production processing. Following validation, the investigators will use the RACs to verify that the data processing produces reasonable results.

Another RAC function is to support flight operations by interfacing with the CMS for instrument microprocessor maintenance and instrument command and control. The baseline approach is to provide this support through the the dedicated communications link between GSFC and the RAC.

Finally, the RACs can be used to access real-time data or quick-look data. This will aid in determining instrument health and safety as well as instrument performance.

An additional requirement is that the RAC functions should be able to occur simultaneously. Because several of the RAC functions require communications with the CDHF, RAC communications capability will support several simultaneous users per RAC. The number of users will be limited only by DECnet capability, and no hardware or software will be added to limit that number.

6.3.6 Communications Requirements

DECnet will be used between the CDHF and the RACs. This allows the use of well established vendor software at the RACs.

For those RACs that support data processing software development, the baseline initial communications capability will have the rate of 9600 bits per second. Because of packet overhead and error-correction overhead, the effective data transfer rate will be less.

About 18 months prior to launch, the remaining RACs will be connected to the CDHF. At that time, several RACs already connected to the CDHF will have their line speeds increased to 56 kbps. All RACs will continue to have communications capabilities with the CDHF for one year beyond the end of useful observatory operations. The data rates for each RAC will be determined at least 2 years prior to launch.

6.3.7 Data Access Requirements

The Science Team will have read privileges to all cataloged data. Any RAC user will be able to access any data file in the CDHF for which he has read privileges.

The final version of Level 3 data will be furnished to the NSSDC for public dissemination. The time at which the final processing step will occur will be determined by the Project Scientist.

APPENDICES

Appendix A: UARS Participants and Contractors

Program Office

Office of Space Science and Applications
Earth Science and Applications Division
NASA Headquarters Code E
Washington, DC 20546

Project Office

National Aeronautics and Space Administration
Goddard Space Flight Center
Flight Projects Directorate Code 430
Greenbelt, Maryland 20771

Contractor (Observatory)

General Electric Company
Astro-Space Division
P.O.Box 8555
Philadelphia, Pennsylvania 19101

Contractor (MMS & UASE)

Fairchild Space Company
20301 Century Boulevard
Germantown, Maryland 20874

Consultant (to GSFC)

Computer Technology Associates, Inc.
7501 Forbes Boulevard, Suite 201
Lanham, Maryland 20706

Instruments

University of Michigan (HRDI)
Space Physics Research Laboratory
2455 Hayward
Ann Arbor, Michigan 48109

York University (WINDII)
Centre for Research in Experimental Space Science
4700 Keele Street
Downsview, Ontario, Canada
M3J 1P3

University of Colorado (SOLSTICE)
Laboratory for Atmospheric and Space Physics
Boulder, Colorado 80309

Naval Research Laboratory (SUSIM)
Solar Physics Branch
Code 4160
Washington, DC 20375

Southwest Research Institute (PEM)
Department of Space Sciences
P.O.Drawer 28510
San Antonio, Texas 78284

Jet Propulsion Laboratory (ACRIM II)
4800 Oak Grove Drive
Mail Stop 171-400
Pasadena, California 91103

Lockheed Palo Alto Research Laboratory (CLAES)
Department 97-90, Building 201
3251 Hanover Street
Palo Alto, California 94304

University of Oxford (ISAMS)
Department of Atmospheric Physics
Clarendon Laboratory
Oxford OX1 3PU
United Kingdom

Jet Propulsion Laboratory (MLS)
4800 Oak Grove Drive
Mail Stop 168-314
Pasadena, California 91103

National Aeronautics and Space Administration (HALOE)
Langley Research Center
Mail Stop 401B
Hampton, Virginia 23665-5225

Contractor (CDHF Software)

Computer Sciences Corporation
System Sciences Division
4600 Powdermill Road
Beltsville, Maryland 20705

Contractor (CDHF Hardware)

Science Systems & Applications Inc.
10210 Greenbelt Road
Suite 640
Lanham, Maryland 20706

Appendix B: List of Abbreviations and Acronyms

A/D	Analog-to-Digital Converter (HALOE)
AAS	Auxiliary Array Switch
ACE	Attitude Control Electronics
ACR	Active Cavity Radiometer
ACRIM II	Active Cavity Radiometer Irradiance Monitor II
ACS	Attitude Control System
AD&C	Attitude Determination and Control
ADC	Analog-to-Digital Converter (HRDI)
AEM	Atmospheric Explorer Mission
AFD	Aft Flight Deck
ATK	Auxillary Tank Kit
AXIS	Atmospheric X-Ray Imaging Spectrometer
BCU	Bus Coupling Unit
BER	bit error rate
bps	bits per second
BPA	Bus Protection Assembly
BRF	Band Reject Filter
C&DH	Communication and Data Handling
C/T	Command Telemetry
CAL	calibration
CCD	Charge Coupled Device
CCE	Capacitively Controlled Etalon (HRDI)
CDB	Correlative Data Basis
CDH	Communication and Data Handling
CDHF	Central Data Handling Facility
CEP	Central Electronics Package (PEM)
CGG	Command Generation Group
CLAES	Cryogen Limb Array Etalon Spectrometer
CMD	command
CMS	Command Management System
CPU	Central Processing Unit
CRC	Cyclical Redundancy Code
CSC	Computer Sciences Corporation
CSS	Coarse Sun Sensor
CU	Central Unit

D	day
D_2	deuterium
DCF	Data Capture Facility
DEC	Digital Equipment Corporation
DECnet	Digital Equipment Corporation Network
deg	degrees
DSN	Deep Space Network
EED	Electro-Explosive Device
EMAF	Engineering Major Frame
EMIF	Engineering Minor Frame
EPROM	Electronically Programmable Read-only Memory (HRDI)
ESAM	Earth Sensor Assembly Module
EU	Expander Unit, Electrical Unit
eV	electron volt
FDF	Flight Dynamics Facility
FHST	Fixed-Head Star Tracker
FMDM	Flexible Multiplexer Demultiplexer
FOT	Flight Operations Team
FOV	Field of View
FSS	Fine Sun Sensor
ft	foot, feet
GE	General Electric
GEA	Gimbal Electronics Assembly (HALOE)
GFE	Government-Furnished Equipment
GHz	gigahertz
GMT	Greenwich Mean Time
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
GSTDN	Ground Spaceflight Tracking and Data Network
H_2	hydrogen
HALOE	Halogen Occultation Experiment
HEPS	High Energy Particle Spectrometer
HGA	High-Gain Antenna
HGAS	High-Gain Antenna System

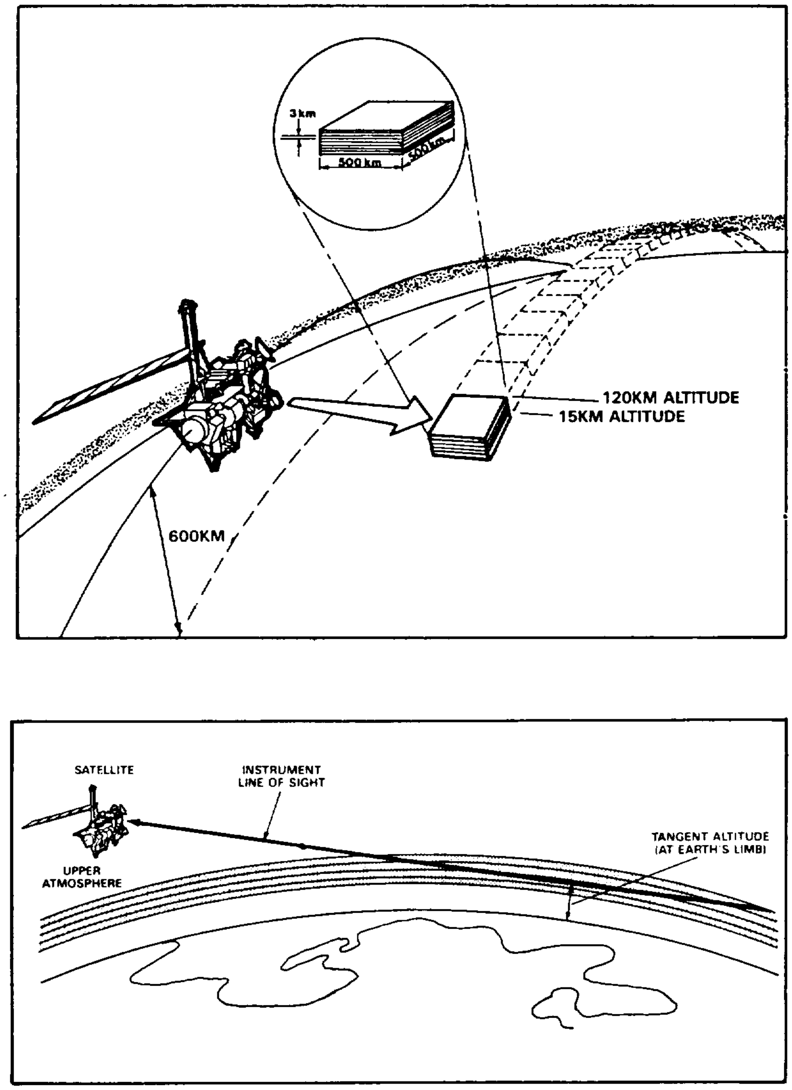
HR	High Resolution (HRDI)
HRDI	High Resolution Doppler Imager
HRS	hours
HV	High Voltage
HVPS	High Voltage Power Supply (PEM)
HVU	High Voltage Unit (PEM)
Hz	hertz
I&T	Integration and Test
I/O	input/output
IFD	In-flight Disconnect
IGSE	Instrument Ground Support Equipment
IM	Instrument Module
IPD	Image Plane Detector (HRDI)
IRU	Inertial Reference Unit
ISAMS	Improved Stratospheric and Mesospheric Sounder
JIS	Joint Integrated Simulation
JISWG	JIS Working Group
JPL	Jet Propulsion Lab
JSC	Johnson Space Center
K	Kelvin
kbps	kilobits per second
KCRT	Keyboard Cathode Ray Tube
kg	kilogram
km	kilometer
KSC	Kennedy Space Center
kw	kilowatt
LAAM	Limb Acquisition Adjustment Mirror (CLAES)
LANDSAT	Land Monitoring Satellite
LaRC	Langley Research Center
lat	latitude
lb	pound
LIMS	Limb Infrared Monitoring of the Stratosphere (HALOE)
LR	Low Resolution (HRDI)

m	meter
MA	Multiple Access
MACS	Modular Attitude Control Subsystem
MAG	Magnetometer (PEM)
matm	milliatmosphere
MCC-H	Mission Control Center-Houston
MEPS	Medium Energy Particle Spectrometer
MHz	megahertz
MI/ITE	Michaelson Interferometer/Inner Thermal Enclosure (WINDII)
min	minute
MIPS	million instructions per second
MLS	Microwave Limb Sounder
mm	millimeter
MMS	Multimission Modular Spacecraft
MO	month
MO&DSD	Mission Operations and Data Systems Directorate
MOR	Mission Operations Room
MPG	Mission Planning Group
MPS	Modular Power Subsystem
MR	Medium Resolution (HRDI)
MSOCC	Multisatellite Operations Control Center
MSS	Module Support System
MTS	Magnetic Torquer System
N	night
NASA	National Aeronautics and Space Administration
NASCOM	NASA Communications Network
NBTR	Narrow-Band Tape Recorder
NCC	Network Control Center
NEPS	Nadir Energetic Particle System
NGT	NASA Ground Terminal
NIE	NEPS Interface Electronics (PEM)
nm	nanometer
NM	Nautical Miles
NMC	National Meteorological Center
NMEPS	Nadir Medium Energy Particle Spectrometer

NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NSI	NASA Standard Initiator
NSP	NASA Support Plan
NSSC	NASA Standard Spacecraft Computer
NSSDC	National Space Science Data Center
nT	nano tesla
OAD	Ordinance Activated Device
OBC	On-board Computer
OSCF	Operations Support Computing Facilty
OSSA	Office of Space Science and Applications
PAD	Pulse Amplifier Discriminator
PCU	Power Control Unit
PDI	Payload Data Interleaver
PDSU	Power Distribution Switching Unit
PEA	Platform Electronics Assembly (HALOE)
PEM	Particle Environment Monitor
PI	Principal Investigator; Payload Interrogator (STS)
PM	Propulsion Module
PM-1A	Propulsion Module
PMP	Pre-Modulator Processor
PMT	Photomultiplier Tube (HRDI)
POCC	Project Operations Control Center
PPM	parts per million
PPS	Programmed Power Supply (PEM)
PRM	Pyro Repeater Module
PRU	Power Regulator Unit
PSP	Payload Signal Processor
PSS	Platform Sun Sensor
PSU	Power Switching Unit
PZT	Piezoelectric Transducer (HRDI)
RAC	Remote Analysis Computer
RF	Radio Frequency
RFIB	RF Interface Box
RIU	Remote Interface Unit

RMS	Remote Manipulator System (STS)
ROEU	Remotely-Operated Electrical Umbilical
ROFU	Remotely-Operated Fluid Umbilical
ROM	Read-only Memory
RPU	Remote Power Unit
RT	Remote Terminal
S/C	Spacecraft
SA	Single Access; Solar Array
SAD	Solar Array Drive
SADAPTA	Solar Array Drive and Power Transfer Assembly
SADDE	Solar Array Drive and Deployment Electronics
SADFDC	Solar Array Drive Failure Detection and Correction
SAGE	Stratospheric Aerosol and Gas Experiment
SAMS	Stratospheric and Mesospheric Sounder
SARDJ	Solar Array Retention, Deployment, and Jettison Parts
SBUV	Solar Backscattered Ultraviolet Spectral Radiometer
SC&CU	Signal Conditioning and Control Unit
SCA	Signal Conditioning Assembly
SCCU	Signal Conditioning and Control Unit
SCIU	Spacecraft Interface Unit
SDVF	Software Development and Validation Facility
SMA	S-Band Multiple Access
SMAF	Science Major Frame
SMIF	Science Minor Frame
SMM	Solar Maximum Mission
SN	Space Network
SOC	Simulation Operations Center
SOLSTICE	Solar Stellar Irradiance Comparison Experiment
SPRU	Standard Power Regulator Unit
SPIF	Shuttle/POCC Interface Facility
SRAM	Static Random Access Memory (HRDI)
SSA	S-Band Single Access
SSP	Standard Switch Panel
SSPP	Solar Stellar Pointing Platform
STACC	Standard Telemetry and Command Components

STINT	Standard Computer Interface Unit
STS	Space Transportation System
SUSIM	Solar Ultraviolet Spectral Irradiance Monitor
SWG	Science Working Group
SYNC	synchronization
T-0	Time Zero (Umbilical)
TAM	Three-axis Magnetometer
TBD	To Be Determined
TBR	To Be Resolved
TCS	Thermal Control Subsystem
TDRS	Tracking and Data Relay Satellite
TDRSS	TDRS System
TE	Thermal Electric
TLM	telemetry
UARS	Upper Atmosphere Research Satellite
UASE	UARS Airborne Support Equipment
UCSS	UARS CDHF Software System
UK	United Kingdom (MLS)
UTTS	UARS Training and Test Simulator
UV	ultraviolet
V	volts
VAX	Virtual Address Extension
VDC	Volts Direct Current
VME	Vector Magnetometer Electronics (PEM)
VMS	Virtual Memory System
W	watts
WINDII	Wind Imaging Interferometer
WSGT	White Sands Ground Terminal
XPDR	Transponder
ZEPS	Zenith Energetic Particle System
ZMEPS	Zenith MEPS



UARS LIMB MEASUREMENTS

UPPER
ATMOSPHERE
RESEARCH
SATELLITE